GJO–2003–427–TAC

Hanford Tank Farms Vadose Zone Monitoring Project

Evaluation of Log Data in the Vicinity of Tank U-107

June 2003

U.S. Department of Energy

Grand Junction Office

Work Performed Under DOE Contract No. DE–AC13–02GJ79491 for the U.S. Department of Energy
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Prepared for
U.S. Department of Energy
Grand Junction Office
Grand Junction, Colorado

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1.0 Introduction

Tank U-107 (U Tank Farm) was selected for proof-of-concept testing to determine the feasibility of saltcake dissolution as a means by which water-soluble salts can be mobilized and retrieved from Hanford Site radioactive waste tanks. The proof-of-concept test utilized a system to dissolve and retrieve a portion of the saltcake as part of, and operating in parallel with, the standard interim stabilization system on tank U-107. This test involved limited volume water sprays over several areas of the waste surface inside tank U-107 to dissolve saltcake. The resulting brine was retrieved at the saltwells. Details of the proof-of-concept test are provided in Estey (2002).

The Hanford Tank Farms Vadose Zone Characterization Project identified baseline conditions in the vicinity of tank U-107. These findings are documented in the Tank Summary Data Report for tank U-107 (DOE 1996b), the U Tank Farm Report (DOE 1997), and the addendum to the U Tank Farm Report (DOE 2000). Hodges and Chou (2000) and Wood and Jones (2003) present further information on subsurface conditions in the vicinity of U Tank Farm and the U waste management area.

In fiscal year (FY) 2001, routine gamma monitoring activities resumed in the single-shell tank (SST) farms, using a simpler system based on NaI detectors, known as the radionuclide assessment system (RAS). Gamma monitoring has been performed on a quarterly basis for existing boreholes around tank U-107 since July 2001. Additional measurements were acquired in July 2001, using the spectral gamma logging system (SGLS) in selected boreholes to assess indications of contaminant migration. Analysis results indicate downward movement of man-made uranium in a pre-existing contaminant plume on the north side of tank U-107 (Henwood 2001).

After the dissolution tests were halted, RAS and neutron moisture logs were run in the boreholes around tank U-107 in March 2003. The results were compared to logs collected in November 2002, immediately before the beginning of the dissolution studies. Increases in moisture content were indicated in the upper 10 ft, most likely resulting from infiltration of precipitation. Below 10-foot (ft) depth, no indication of an increase in either gamma activity or soil moisture content was evident that could be attributed to a leak during the saltcake dissolution studies.

2.0 Purpose and Scope

This report provides a summary of available geophysical logging data in the vicinity of tank U-107 as of March 2003. It provides a description of vadose zone contaminant conditions immediately prior to the initiation of dissolution studies in U-107 and compares pre-dissolution log data to log data collected shortly after dissolution studies were halted. The intent of this report is to assess the effect, if any, of dissolution tests on contamination conditions in the vadose zone around tank U-107.

3.0 Background

3.1 Tank U-107

Tank U-107 is a 75-ft-diameter SST consisting of a steel liner inside a concrete shell with an unlined concrete dome. The tank bottom is dished, with the center being 12 inches (in.) lower than the perimeter. The joint between the tank bottom and sidewalls is a curved "knuckle" with a 4-ft radius. Tank U-107 has a nominal operating capacity of 530,000 gallons (gal). Figure 1 shows a section view of tank U-107.

Tank U-107 was constructed in 1943 and 1944 and put into service in 1948, as the first tank in a three-tank cascade series. The tank initially received metal waste from T Plant operations. Metal waste was accumulated and stored in tank U-107 until 1956, when the tank was sluiced and declared empty. Following sluicing, tank U-107 stored a variety of wastes, including coating waste, evaporator feed and bottoms waste, and decontamination waste. This tank was removed from service and declared inactive in 1980. A brief summary of tank U-107 history is provided in Brevick et al. (1994) and in the tank summary data report for this tank (DOE 1996b). One item of note is the transfer of acidic (pH = 4.2) waste into tank U-107, in violation of operational procedures that specified a pH of greater than 8 for wastes transferred to carbon-steel tanks. Transfers are reported to have occurred at least four times during March and April 1975 (Anderson 1975).

As of October 31, 2002, the tank contained approximately 320,000 gal of waste, of which 305,000 gal are saltcake and 15,000 gal are sludge. The tank is currently categorized as sound. (Hanlon 2003).

3.2 Salt Cake Dissolution Studies

Tank U-107 was selected for the proof-of-concept operations because it contains suitable waste (i.e., saltcake), and interim stabilization activities were scheduled at a time that would complement the proof-of-concept operational activities. The brine produced by saltcake dissolution tests was removed with saltwell pumping equipment.

The saltcake dissolution method is intended to be a cost-effective alternative to sluicing. Major elements of the saltcake dissolution method include:

- Water distribution for saltcake dissolution is accomplished using relatively simple nozzles, which can either be reused or inexpensively disposed;
- Existing saltwell pumping equipment, infrastructure, and expertise developed during interim stabilization activities are used to remove the resulting brine;
- Existing tank farm infrastructure is sufficient to allow retrieval at the anticipated saltcake dissolution rates; and

- An overall lower total volume of water is used, maintaining a generally lower hydraulic head, thus minimizing the risk of leaks.

3.3 Geologic Conditions

Excavation for the U Tank Farm occurred in sediments of the Hanford formation, and the excavated material was used as backfill around the completed tanks. The Hanford formation consists of gravels, sands, and silts deposited by cataclysmic flooding during the Pleistocene. The Hanford formation sediments display high variability in grain size, sorting, and distribution over short vertical and lateral extents. The Hanford formation sediments consist mainly of gravelly sand and silty sandy gravel and extend to a depth of about 100 ft in the vicinity of the U Tank Farm. Beneath the Hanford formation sediments is a sequence of slightly silty sand and silty sand previously identified as the undifferentiated Plio-Pleistocene unit. Under the revised stratigraphic nomenclature (DOE 2002), this unit is now known as the Cold Creek unit. Underlying this unit at a depth of about 130 ft are silty sandy gravels and sandy gravels of the middle Ringold Formation. The top of the water table occurs at a depth of about 226 ft below ground surface (Hodges and Chou 2000).

Price and Fecht (1976) first described geologic conditions beneath the U Tank Farm. Caggiano and Goodwin (1991) reviewed historical geologic data and compiled geologic cross sections. More recent discussions of suprabasalt stratigraphy are available in Lindsey (1996) and Williams et al. (2002). Geology and groundwater conditions in the U waste management area are also summarized in Hodges and Chou (2000) and Wood and Jones (2003).

3.4 Existing Boreholes in the Vicinity of Tank U-107

The seven vadose zone monitoring boreholes surrounding tank U-107 were drilled in the mid-1970s, almost 30 years after the tank went into service. These monitoring boreholes range from 100 to 125 ft in depth and are located at distances ranging from 7 to 20 ft outside the steel tank liner. Figure 2 shows the location of monitoring boreholes in the vicinity of tank U-107.

Monitoring boreholes in U Tank Farm are generally completed with a 6-in.-inside-diameter (ID) casing. The surface exposures of most of the borehole casings are flush with a small diameter concrete marker, making accurate measurements of the borehole casing wall thickness difficult. Therefore, the casing wall thickness used to determine radionuclide concentrations is based on the published thickness for schedule-40, carbon-steel casing, which is the typical casing used in tank farm borehole construction. These values are 6.625-in. outer diameter (OD), 0.280-in. wall thickness, and 6.065-in. ID. Evaluation of the borehole construction records indicates that at least three of the boreholes were drilled with an 8-in. casing from ground surface to 20-ft depth. The 8-in. casing was subsequently withdrawn and the annulus outside the 6-in. casing was filled with grout. Table 1 provides a summary of boreholes in the vicinity of tank U-107.

Table 1. Summary of Boreholes in the Vicinity of Tank U-107

Borehole	Depth (ft) *(elevation)*	Casing	Logs Type[1]	Logs Date	Logs Interval (ft)	Comments
60-07-01	105	6"ID	TFGG(4)	07/08/76	0-98	earliest available log
299-W18-114		0.28"	TFGG(4)	10/26/93	0-98	
A7597	*(665)*		SGLS (1A)	11/02/95	0-98.5	baseline
		8" surf	SGLS (2B)	05/03/99	50-85	
N38043		*casing &*	RAS (L)	07/12/01	40-98.5	
W75617		*grout to*	SGLS (2B)	07/26/01	20-93	
		20 ft	RAS (L)	10/04/01	40-98.5	
N135056.201			RAS (L)	12/26/01	40-98.5	
E566848.149			RAS (L)	04/10/02	40-98.5	
			RAS (L)	08/23/02	40-98.5	
			RAS (L)	11/05/02	40-98.5	
			NMLS	11/13/02	0-98	
			RAS (L)	03/05/03	0-98	post test
			NMLS	03/06/03	0-98	post test
60-07-02	125	6"ID	TFGG(4)	01/09/75	0-100	earliest available log
299-W19-74		0.28"	TFGG(4)	10/26/93	0-100	
A7774	*(668.45)*		SGLS (1A)	11/06/95	0-126	baseline
			RAS (L)	07/12/01	35-100	
N38017			RAS (L)	10/04/01	35-100	
W75594			RAS (L)	12/26/01	35-100	
			RAS (L)	04/15/02	35-100	
N135048.71			RAS (L)	08/23/02	35-100	
E566848.382			RAS (L)	11/04/02	35-125	
			NMLS	11/13/02	0-125	
			RAS (L)	03/05/03	0-125	post test
			NMLS	03/06/03	0-125	post test
60-10-01	125	6"ID	TFGG(4)	01/09/75	0-125	earliest available log
299-W18-100		0.28"	TFGG(4)	05/31/94	0-125	
A7583	*(667.74)*		SGLS (1A)	11/29/95	0-125	baseline
			RAS (L)	07/17/01	40-60	
N37942			RAS (L)	10/04/01	35-75	
W75616			RAS (L)	12/27/01	35-75	
			RAS (L)	04/11/02	35-75	
N135025.82			RAS (L)	08/26/02	35-75	
E566848.382			RAS (L)	11/06/02	35-125	
			NMLS	11/14/02	0-125	
			RAS (L)	03/03/03	0-125	post test
			NMLS	03/04/03	0-125	post test

[1] The abbreviation denotes the logging system and detector:
TFGG(4) = tank farms gross gamma logs 4 = scintillator (NaI)
SGLS(1A) = spectral gamma logging system, (Gamma 1A)
RAS(L) = radionuclide assessment system (large detector)
NMLS = neutron moisture logging system

Table 1 (con't). Summary of Boreholes in the Vicinity of Tank U-107

Borehole	Depth (ft) *(elevation)*	Casing	Logs Type	Logs Date	Logs Interval (ft)	Comments
60-10-11 299-W18-107 A7590 N37943 W75657 N135026.158 E566835.614	105	6"ID 0.28" *8" surf casing & grout to 20 ft*	TFGG(4)	07/08/76	0-100	earliest available log
			TFGG(4)	05/31/94	0-100	
			SGLS (1A)	11/22/95	0-98	baseline
			RAS (L)	07/17/01	40-60	
			RAS (L)	10/04/01	35-75	
			RAS (L)	01/02/02	35-75	
			RAS (L)	04/11/02	35-75	
			RAS (L)	08/26/02	35-75	
			RAS (L)	11/07/02	35-98	
			NMLS	11/14/02	0-98	
			RAS (L)	03/03/03	0-98	post test
			NMLS	03/04/03	0-98	post test
			TFGG(4)	05/31/94	0-100	
			SGLS (1A)	11/22/95	0-98	baseline
			RAS (L)	07/17/01	40-60	
			RAS (L)	10/04/01	35-75	
			RAS (L)	01/02/02	35-75	
			RAS (L)	04/11/02	35-75	
			RAS (L)	08/26/02	35-75	
			RAS (L)	11/07/02	35-98	
			NMLS	11/14/02	0-98	
			RAS (L)	03/03/03	0-98	post test
			NMLS	03/04/03	0-98	post test
			NMLS	03/05/03	0-127	post test
			RAS(L)	03/06/03	0-127	post test
60-07-10 299-W18-116 A7599 N38017 W75678	105 *(665)*	6"ID 0.28" *8" surf casing & grout to 20 ft.*	TFGG(4)	07/08/76	0-97	earliest available log
			TFGG(4)	11/02/93	0-97	
			SGLS (1A)	11/09/95	0-98	baseline
			SGLS (2B)	04/29/99	45-85	
			RAS (L)	07/09/01	40-98	
			SGLS (2B)	07/26/01	20-98.5	
			RAS (L)	10/24/01	50-80	
			RAS (L)	12/27/01	40-98	
			RAS (L)	04/15/02	40-98	
			RAS (L)	08/26/02	40-98	
			RAS (L)	11/05/02	40-98	
			NMLS	11/12/02	0-98	
			RAS (L)	03/06/03	0-98	post test
			NMLS	03/07/03	0-98	post test

Table 1 (con't). Summary of Boreholes in the Vicinity of Tank U-107

Borehole	Depth (ft) *(elevation)*	Casing	Logs Type	Logs Date	Logs Interval (ft)	Comments
60-07-11	125	6"ID	TFGG(4)	01/09/75	0-125	earliest available log
299-W18-117		0.28"	TFGG(4)	10/26/93	0-125	
A7600	*(666.47)*		SGLS (1A)	11/08/95	0-124	baseline
			SGLS (2B)	05/03/99	50-95	
N38043			RAS (L)	07/12/01	40-100	
W75657			SGLS (2B)	07/27/01	20-102	
			RAS (L)	10/24/01	40-100	
N135056.429			RAS (L)	12/27/01	40-100	
E566835.967			RAS (L)	04/15/02	40-100	
			RAS (L)	08/26/02	40-100	
			RAS (L)	11/05/02	40-124	
			NMLS	11/12/02	0-124	
			RAS (L)	03/05/03	0-124	post test
			NMLS	03/06/03	0-124	post test

Available log data include gross gamma logs collected by tank farms personnel until 1994. Most of these data were acquired with a NaI scintillation detector (probe 4). Beginning in 1975, these logs were stored in electronic format. Randall and Price (2001) have evaluated gross gamma logs for all U Tank Farm boreholes. In 1995, high-resolution spectral gamma logs were collected with the SGLS by the Hanford Tank Farms Vadose Zone Characterization Project. Supplemental SGLS logging was performed in selected borehole intervals in 1999.

Beginning in July 2001, routine monitoring measurements have been acquired on a quarterly basis. The Hanford Tank Farms Vadose Zone Monitoring Project was established to periodically monitor vadose zone gamma activity in selected depth intervals within existing monitoring boreholes adjacent to SSTs. Gamma activity is compared to activity detected during the baseline characterization of the same boreholes conducted between 1995 and 2000 to detect any changes. Monitoring frequency is determined on the basis of existing contamination levels, plume behavior, tank characteristics, and tank farm operational requirements.

In July 2001, a special investigation was prompted when the RAS data indicated possible migration of processed uranium in the vicinity of tanks U-104 and U-107. Because it had been 2 years since the last log data were collected in boreholes in the area of the plume, it was deemed necessary to document any changes in the contaminant levels prior to the initiation of dissolution tests in tank U-107. To accomplish this task, a combination of logging using the RAS and SGLS was performed in specified boreholes. All boreholes in the vicinity of tank U-107 were logged with the RAS to provide a baseline to which subsequent RAS logs can be compared to detect contaminant movement. In addition, selected borehole intervals on the north side of tank U-107 were relogged with the SGLS to detect changes that may be indicative of radionuclide movement. Since July 2001, boreholes in the vicinity of U-107 have been logged with the RAS on a quarterly basis. Neutron moisture logs were also collected in November 2002 and March 2003, in conjunction with the most recent monitoring events.

4.0 Discussion of Individual Boreholes

Data for individual boreholes are discussed below. Combination plots from the original baseline logs are included for each borehole and additional plots are provided to illustrate subsequent data. To eliminate the potential for apparent changes based on differences in interpretation, concentrations on the SGLS log plots have been recalculated from peak count rates, using the same casing correction factor. Where appropriate, data have been corrected for decay to December 31, 2002. (Note that the combination plots have not been corrected.)

4.1 Borehole 60-07-01

Borehole 60-07-01 is located approximately 12 ft from the northeast side of tank U-107. It was drilled in 1976 to a depth of 105 ft and completed with 6-in. carbon steel casing. It appears that drilling of this borehole may have been started with 8-in. casing that was removed at the completion of drilling, and the annulus around the 6-in. casing was filled with grout. Ten sacks of cement grout were used during borehole completion; however, the location of grout placement was not documented (DOE 1996b).

Figure 3 is a combination plot of the baseline data for borehole 60-07-01. Figures 4 and 5 are additional plots showing SGLS and RAS data for total gamma activity and ^{234}Pa (man-made ^{238}U). Neutron moisture log data are included on both the total gamma and ^{234}Pa plots.

SGLS logging from 0- to 98.5-ft depth was completed in November 1995. ^{137}Cs was detected intermittently from the ground surface to a depth of 14 ft. The maximum subsurface concentration of 9 picocuries per gram (pCi/g) was measured at a depth of 0.5 ft. This contamination resulted from a surface spill.

Man-made ^{235}U and ^{238}U were detected in this borehole, beginning at a depth of 52 ft. Man-made uranium is identified on the basis of specific energy peaks not generally detectable at background levels of naturally occurring uranium. Detection of ^{235}U is based on the 185.7-kilo-electron-volt (keV) gamma ray, with a minimum detectable level (MDL) of about 0.6 pCi/g, and ^{238}U is based on the 1001-keV gamma ray, with an MDL of about 12 pCi/g. ^{235}U was detected continuously at depths from 52 to 57 ft, from 73 to 77 ft, intermittently between these two zones, and slightly below the lower zone. The maximum concentration of approximately 9 pCi/g was measured at a depth of 55 ft. ^{238}U was detected continuously at depths from 52 to 58 ft, from 73 to 81 ft, and intermittently between these two zones. ^{238}U concentrations between 100 and 200 pCi/g were measured between 52 and 56 ft in depth. The processed uranium is most likely associated with leakage from tank U-104. It is possible that the uranium distribution is continuous through this zone slightly below the MDL.

In May 1999, the interval from 50 to 85 ft was relogged with the SGLS. Uranium concentrations were similar to those observed in 1995, with the exception that processed uranium was detected from 52 to 58 ft and from 75 ft to the bottom of the logged interval at 85 ft, at least 4 ft deeper than observed in 1995. When the borehole was again logged with the SGLS in July 2001, the lower extent of uranium was detected at a depth of 89 ft. Uranium concentrations appear to be relatively stable in the zone from 52 to 58 ft, decreasing slightly from 73 to 81 ft, and increasing from 83 to 89 ft.

Historical tank farms gross gamma-ray logging data from 1976 to 1994 were reviewed (Welty 1988). A zone of elevated gamma-ray activity was identified in the earliest log data at a depth of 53 ft. The elevated gamma-ray activity is related to the occurrence of processed ^{235}U and ^{238}U detected by the SGLS. Historical data suggest that the uranium peak at 53 to 56 ft may have migrated downward from 48 to 52 ft between 1976 and 1982, although it is possible that some of the apparent movement may be due to inconsistencies in depth registration.

Randall and Price (2001) evaluated the grade thickness product (GTP) over the interval of 48 to 62 ft as decreasing from 1976 to 1984 and constant from 1984 to 1993. The stability classification of this zone is listed as “undetermined.”

Seven RAS log runs were performed in the interval from 40- to 98-ft depth between July 2001 and March 2003. A comparison of plots of both total counts and ^{234}Pa counts (processed uranium) shows no significant change in this interval (Figure 5).

A neutron moisture log was run on November 13, 2002. Evaluation of this log indicates the grout may have extended as deep as 25 ft. This is also the depth at which an abrupt increase in ^{40}K is observed in the SGLS log. A thin zone of about 15 vol % moisture content occurs at 52 ft. This appears to be just above the maximum uranium concentration observed in the borehole. A second increase in moisture content (to about 11 vol %) occurs at 62 to 65 ft, but this has not been associated with increased contamination. From 82 to 96 ft, moisture content varies from a minimum value of 4 to 6 vol % to peak values between 10 and 14 vol % at 83, 87, 92, and 95 ft. This variation suggests thinly bedded material with varying moisture content in an interval where downward migration of uranium appears to be occurring.

A RAS log run was conducted on March 5, 2003, after dissolution testing had been completed. Comparison with pre-test log data indicates no detectable change. Neutron moisture logs conducted on March 6, 2003 also exhibit no change from logs run prior to testing. However, neutron response in the shallow vadose zone is obscured by the grout.

4.2 Borehole 60-07-02

Borehole 60-07-02 is located approximately 9 ft from the northeast side of tank U-107. This borehole was drilled in 1974 to a depth of 125 ft and was completed with 6-in. carbon steel casing. The present top of the casing, which is the zero reference for logging depth locations, is on the slope of a hill approximately 2.5 ft above the surrounding ground surface. This borehole was not perforated or grouted (DOE 1996b).

Figure 6 is a combination plot of the baseline data for borehole 60-07-02. Figure 7 presents additional plots showing SGLS and RAS data for total gamma activity and neutron log data.

Baseline SGLS data were collected for this borehole in November 1995. ^{137}Cs was continuously detected from the ground surface to a depth of about 21 ft, intermittently at depths from 22 to

36 ft, and at the bottom of the borehole. The maximum ^{137}Cs concentration of about 15 pCi/g was measured at a depth of 3 ft. The ^{137}Cs contamination resulted from a near-surface spill. The contamination near the bottom of the borehole probably migrated down the inside of the casing.

No evidence of processed uranium was detected in this borehole.

The earliest to most recent tank farms gross gamma-ray log data were reviewed Welty (1988). No activity over 50 counts per second (cps) was listed in the tabulated gross gamma-ray data from 1974 to 1985. Elevated activity at or near ground surface was often considered to be from non-tank source(s) and was not reported. The earliest (1985) to most recent (1993) log plots show increased gamma activity at depths from 5 to 22 ft that is related to the ^{137}Cs contamination observed by the SGLS.

Randall and Price (2001) evaluated the GTP for the interval from 0 to 24 ft from gross gamma logs collected between 1975 and 1993, concluding that the contamination was stable over this time period.

Between July 2001 and March 2003, seven log runs were made with the RAS for the interval between 35 and 100 ft. A comparison between these runs and the 1995 SGLS data indicates the same general character, and there is no significant difference between successive RAS logs. A comparison of log data from March 2003 with log data collected in November 2002 shows no evidence of any increase in activity that might be associated with the dissolution studies.

A neutron moisture log collected on November 13, 2002 exhibits a similar profile to that of borehole 60-07-01. There is no evidence of grout in the upper 25 ft. Moisture peaks occur at 36, 54, 65, 74, 76.5, and 81.5 ft. Below 85 ft, moisture values are higher, but variable, ranging between 5 and 10 percent by volume. A second neutron moisture log was completed on March 6, 2003. A comparison of the two moisture logs indicated an increase of about 2 vol % water in the upper 11 ft, with no significant change in moisture content below 11 ft. The observed changes in moisture in the upper 11 ft can be attributed to infiltration of precipitation.

4.3 Borehole 60-10-01

Borehole 60-10-01 is located approximately 19 ft from the southeast side of tank U-107, adjacent to tank U-110. This borehole was drilled in 1974 to a depth of 125 ft and completed with 6-in. carbon steel casing. The top of the casing, which is the zero reference for the logging depth, extends about 0.5 ft above a berm that is about 0.5 ft above the surrounding U Tank Farm surface. This borehole was not perforated or grouted (DOE 1996b).

Figure 8 is a combination plot of the baseline data for borehole 60-10-01. Figure 9 presents additional plots showing SGLS and RAS data for total gamma activity and neutron log data.

Baseline SGLS data were collected in November 1995. ^{137}Cs was continuously detected from the ground surface to a depth of 28 ft, intermittently at depths from 32 to 41.5 ft, at 78 ft, and at the bottom of the borehole. ^{137}Cs concentrations ranged between 0.2 and 9 pCi/g. The maximum ^{137}Cs concentration of 9 pCi/g was measured at a depth of 6.5 ft. This contamination most likely resulted from a surface or near-surface spill.

No evidence of processed uranium was detected in this borehole.

Historical tank farms gross gamma-ray logging data were reviewed for this borehole. Log plots were not available for logging earlier than 1982, and the tabulated data in Welty (1988) do not identify any elevated gamma-ray activity. This lack of logging data probably results from the practice of concentrating on tank leaks and not on contamination above tank waste levels. The log plots from 1982 to 1989 identify elevated gamma-ray activity at levels 2 to 3 times the background in the upper 10 ft of the borehole. This elevated activity is related to the ^{137}Cs detected by the SGLS.

Randall and Price (2001) evaluated the GTP from 0 to 14 ft in historical gross gamma data from 1975 to 1994. They found it to be erratic and indicative of tank farm activity over this period.

Between July 2001 and March 2003, seven log runs were made with the RAS for the interval between 35 and 75 ft. A comparison between these runs and the 1995 SGLS data indicates the same general character, and there is no significant difference between successive RAS logs. Comparison of log data from March 2003 with log data collected in November 2002 shows no evidence of any increase in gamma activity that might be associated with the dissolution studies.

A neutron moisture log collected on November 14, 2002 shows no evidence of grout in the upper 25 ft. Volumetric moisture content increases from 0 at ground surface to approximately 6.5 percent at 4 ft. Between 4 and 47 ft, the moisture content ranges between 5 and 10 percent, with peaks at 37.5 and 46 ft. From 47 ft to the bottom of the borehole, the moisture content is more variable, with a minimum value between 2 to 3 percent and numerous thin zones with 12 to 15 percent moisture.

A second neutron moisture log was completed on March 4, 2003. A comparison of the two moisture logs indicated an increase of about 2 vol % water in the upper 2 to 11 ft, with no significant change in moisture content below 11 ft. The observed changes in moisture in the upper 11 ft can be attributed to infiltration of precipitation.

4.4 Borehole 60-10-11

Borehole 60-10-11 is located approximately 18 ft from the southwest side of tank U-107, adjacent to tank U-110. This borehole was drilled in 1976 to a depth of 105 ft and was completed with 6-in. carbon steel casing. The first 20 to 25 ft of this borehole appear to have been drilled with 8-in.-diameter casing that was removed with grout added to the annulus around the 6-in. casing. The bottom 5 ft of the borehole was also grouted. The top of the casing for this borehole is 2 to 3 ft above the surrounding ground surface of the U Tank Farm (DOE 1996b).

Figure 10 is a combination plot of the baseline data for borehole 60-10-11. Figure 11 presents additional plots showing SGLS and RAS data for total gamma activity and neutron log data.

^{137}Cs was intermittently detected from the ground surface to a depth of about 14.5 ft, at a depth of 23 ft, and at the bottom of the borehole. The ^{137}Cs concentrations in the near-surface zone ranged between 0.2 and slightly less than 6 pCi/g. The highest concentration was measured at a depth of 1.5 ft. This contamination most likely resulted from surface contamination.

No evidence of processed uranium was detected in this borehole.

The historical tank farms gross gamma-ray data tabulated in Welty (1988) were reviewed because no log plots earlier than 1985 were available. The tabulated data do not identify elevated gamma-ray activity above 50 cps in this borehole. The first log plot from 1985 identified elevated gamma-ray activity near the ground surface, and elevated activity was observed at the ground surface on the most current (1994) gross gamma-ray log plot.

Randall and Price (2001) evaluated the GTP from 0 to 14 ft in historical gross gamma data from 1976 to 1994. They found it to be erratic and indicative of tank farm activity over this period.

Between July 2001 and March 2003, seven log runs were made with the RAS for the interval between 35 and 75 ft. Comparison between these runs and the 1995 SGLS data indicates the same general character, and there is no significant difference between successive RAS logs. A comparison of log data from March 2003 with log data collected in November 2002 shows no evidence of any detectable increase in gamma activity that might be associated with the dissolution studies.

A neutron moisture log collected on November 14, 2002 shows evidence of grout between ground surface and 23 ft. This is consistent with the ^{40}K plot. Below 23 ft, volumetric moisture content ranges from 3 to 8 percent. Below the backfill, moisture decreases slightly with thin zones up to 13 percent at 55 ft and 11.5 percent at 66 ft. Below 85 ft, the moisture content increases and becomes more variable, ranging between 6 and 12 percent.

A second neutron moisture log was completed on March 4, 2003. A comparison of the two moisture logs indicated no increase in volumetric moisture content.

4.5 Borehole 60-08-04

Borehole 60-08-04 is located approximately 20 ft from the southwest side of tank U-107, adjacent to tank U-108. This borehole was drilled in 1974 to a depth of 125 ft and was completed with 6-in. carbon steel casing. This borehole is located on a berm that is about 3 ft above the surrounding ground surface (DOE 1996b).

Figure 12 is a combination plot of the baseline data for borehole 60-08-04. Figures 13 and 14 present additional plots showing SGLS and RAS data for total gamma activity and ^{234}Pa (man-made ^{238}U). Neutron log data are included on both the total gamma and ^{234}Pa plots.

Low levels of ^{137}Cs were detected almost continuously from the ground surface to a depth of 20 ft, from 25.5 to 31.5 ft, and at a few isolated locations near the bottom of the borehole. The ^{137}Cs concentrations in the continuous zone ranged between 0.2 and 3 pCi/g. The maximum subsurface concentration of 3 pCi/g was measured at a depth of 3.5 ft. The broad peak of ^{137}Cs contamination from the ground surface to a depth of 5 ft may be related to the proximity of the borehole to a transfer pipeline within the berm. The logging tool probably detected ^{137}Cs contamination in the pipeline. ^{137}Cs below this zone probably resulted from downward migration of a surface or near-surface spill.

^{154}Eu was detected at depths from 2 to 4 ft, and may also be related to contamination in a nearby pipeline. ^{154}Eu concentrations ranged between 0.4 to slightly more than 1 pCi/g.

Man-made ^{235}U and ^{238}U were detected in this borehole. ^{235}U was detected in a 1-ft-thick interval at a depth of 55 ft. The maximum concentration was about 15 pCi/g. ^{238}U was detected at 54.5 to 55.5 ft, at 65 ft, and at 67.5 ft. The maximum concentration was 240 pCi/g at 55 ft.

In April 1999, the interval from 50 to 70 ft was relogged with the SGLS. Uranium concentrations were similar to those observed in 1995. Total counts were slightly elevated relative to the 1995 data over the entire depth interval of the 1999 log, but no additional radionuclides were detected. The discrepancy between gross count rates is probably related to a slight difference in detector efficiencies between the two different SGLSs.

Between July 2001 and March 2003, seven log runs were conducted with the RAS for the interval between 35 and 100 ft. A comparison between these runs and the SGLS total gamma data indicates the same general character, and there is no significant difference between successive RAS logs. A comparison of log data from March 2003 with log data collected in November 2002 shows no evidence of any increase in gamma activity that might be associated with the dissolution studies. A review of the historical tank farms gross gamma-ray log data from 1974 to the most recent (1993) shows an elevated peak of activity at a depth of about 54 ft. The intensity of this peak, which reached a maximum in 1983, diminished and has remained stable. This peak of elevated activity is associated with the processed uranium contamination identified with the SGLS.

Randall and Price (2001) evaluated the GTP from 0 to 10 ft and 50 to 60 ft in historical gross gamma data from 1975 to 1993. The GTP from 0 to 10 ft appeared to be erratic and indicative of tank farm activity over this period. The GTP from 50 to 60 ft showed a slight increase from 1975 to 1983, and then appeared to be constant from 1984 to 1993, after a data gap in 1983. The category of this zone was undetermined.

A neutron moisture log collected on November 13, 2002 shows no evidence of grout in the upper 25 ft, but moisture appears to be anomalously high. Volumetric moisture content increases from 0 at ground surface to about 17 percent at 18 ft, and then decreases to 7 percent at 25 ft. Between 26 and 31 ft, the moisture content ranges between 10 and 12 percent. From 31 to 53 ft, the volumetric moisture content decreases from 6 to 5 percent with peaks at 38 ft and 48 ft, where the moisture content is between 8 and 9 percent. A thin zone of up to 15 percent moisture content at 55 ft coincides with elevated uranium concentrations. From 56 to 85 ft moisture content is generally 2 to 4 percent, with thin zones of up to 8 percent at 65, 76, and 81 ft. Below 85 ft, the neutron moisture curve increases and becomes variable, ranging from 5 to 15 percent. An interval between 118 and 123 ft has a moisture content less than 5 percent.

A second neutron moisture log was completed on March 5, 2003. A comparison of the two moisture logs indicated an increase of about 2 vol % water in the upper 9 ft, with no significant change in moisture content below 9 ft. The observed changes in moisture in the upper 9 ft can be attributed to infiltration of precipitation.

4.6 Borehole 60-07-10

Borehole 60-07-10 is located approximately 7 ft from the northwest side of tank U-107. This borehole was drilled in 1976 to a depth of 105 ft and was completed with 6-in. carbon steel casing. The first 20 ft of the borehole was drilled with 8-in. casing. Upon completion of the borehole, the 8-in. casing was removed and grout was placed in the annulus on the outside of the 6-in. casing. The 6-in. casing was backpulled 5 ft, and the bottom of the borehole was grouted to a total depth of 100 ft. Ten sacks of cement were used to grout the borehole (DOE 1996b).

Figure 15 is a combination plot of the baseline data for borehole 60-07-10. Figures 16 and 17 present additional plots showing SGLS and RAS data for total gamma activity and ^{234}Pa (man-made ^{238}U). Neutron log data are included on both the total gamma and ^{234}Pa plots.

^{137}Cs was continuously detected from the ground surface to a depth of 8 ft, intermittently at depths from 10 to 16 ft, at a few isolated locations, and at the bottom of the borehole. The ^{137}Cs concentrations ranged from 0.2 to slightly more than 6 pCi/g. This contamination most likely resulted from a surface or near-surface spill. Man-made ^{235}U and ^{238}U were detected in this borehole. ^{235}U was detected from 52 to 54 ft, from 57 to 74 ft, and at 77 ft. The maximum ^{235}U concentration of slightly more than 40 pCi/g was measured at 53 ft. Concentrations in the zone from 57 to 74 ft ranged between 1 and 20 pCi/g. ^{238}U was detected at 52 to 54 ft and from 57 to 78 ft. The maximum ^{238}U concentration of almost 1,000 pCi/g was measured at 53 ft. Concentrations in the zone from 57 to 78 ft ranged from 0.2 to 300 pCi/g. The uranium most likely resulted from leakage from tank U-104.

In April 1999, the interval from 45 to 85 ft was relogged with the SGLS. Uranium concentrations were similar to those observed in 1995, with the exception that processed uranium was detected from 52 to 54 ft, and from 57 to 80 ft, at least 4 to 6 ft deeper than observed in 1995. When the borehole was again logged with the SGLS in July 2001, the lower extent of uranium was detected at a depth of 83.5 ft. Uranium concentrations appear to be relatively stable in the zone from 52 to 74 ft, and increasing below 74 ft (between 1999 and 2001).

Between July 2001 and March 2003, 7 log runs were conducted with the RAS for the interval between 40 and 98 ft. Comparison between these runs and the 1995 SGLS data indicates the same general character and there is no significant difference between successive RAS logs. A comparison of log data from March 2003 with log data collected in November 2002 shows no evidence of any short-term increase in gamma activity that might be associated with the dissolution studies.

Log plots earlier than 1986 were not available for this borehole; therefore, the tabulated tank farms gross gamma-ray log data recorded in Welty (1988) were reviewed. An elevated peak of gamma activity was detected in the earliest (1976) data at a depth of about 51 ft, and the activity reached a maximum intensity in 1979. Log plots from 1986 to the present indicate a peak of slightly decreasing activity at a depth of 54 ft. This peak occurs within a broader zone of elevated activity between depths of 52 and 66 ft. This elevated activity is related to the ^{235}U and ^{238}U identified with the SGLS.

Randall and Price (2001) evaluated the GTP for the interval from 48 to 70 ft in tank farm gross gamma logs between 1976 and 1993. An increase was observed between 1978 and 1980, and the stack plots of individual logs indicated that the thickness of the contaminated zone increased from 57 to 60 ft in 1976 to 57 to 66 ft in 1985. This zone was classified as “unstable early.”

A neutron moisture log collected on November 12, 2002 shows evidence of grout between ground surface and 30 ft. The ^{40}K log shows changes at 20 and 29 ft that may be related to grout, but they are not conclusive. A thin zone of elevated moisture (about 15 percent) occurs at 53 ft, which is coincident with the uranium anomaly. Below 54 ft, moisture content is typically 2 to 4 percent, with peaks of 8 percent at 64, 75, and 83.5 ft. Thin zones of 14 to 15 percent occur at 86 and 92 ft.

A second neutron moisture log was completed on March 7, 2003. A comparison of the two moisture logs indicated no increase in volumetric moisture content.

4.7 Borehole 60-07-11

Borehole 60-07-11 is located approximately 12 ft from the northwest side of tank U-107. This borehole was drilled in 1974 to a depth of 125 ft and was completed with 6-in. carbon steel casing. Borehole 60-07-11 was not perforated or grouted. The top of the casing, which is the zero depth reference for the SGLS log data, is approximately 6 in. above the ground surface (DOE 1996b).

Figure 18 is a combination plot of the baseline data for borehole 60-07-11. Figures 19 and 20 present additional plots showing SGLS and RAS data for total gamma activity and ^{234}Pa (manmade ^{238}U). Neutron log data are included on both the total gamma and ^{234}Pa plots.

^{137}Cs was detected from the ground surface to a depth of about 8 ft, from 13 to 17 ft, at a few isolated locations, and at the bottom of the borehole. The maximum ^{137}Cs concentration of almost 20 pCi/g was detected at a depth of 1 ft. This contamination resulted from a surface or near-surface spill.

Man-made ^{235}U and ^{238}U were detected. ^{235}U was continuously detected at depths from 52 to 82 ft and from 83 to 93 ft. Concentrations ranged between 1 and 80 pCi/g. The maximum ^{235}U concentration of 80 pCi/g was measured at a depth of 53 ft. ^{238}U was continuously detected at depths from 52 to 69 ft, from 70 to 82 ft, and from 83 to 93 ft. Concentrations ranged between almost 30 to more than 1,000 pCi/g. The maximum ^{238}U concentration of more than 1,000 pCi/g was measured at a depth of 53 ft. The processed uranium contamination most likely resulted from leakage of tank U-104.

In May 1999, the interval from 50 to 95 ft was relogged with the SGLS. Uranium concentrations were similar to those observed in 1995, with the exception that processed uranium was detected to the bottom of the log interval at 95 ft, at least 3 ft deeper than observed in 1995. When the borehole was again logged with the SGLS in July 2001, the lower extent of uranium was found at a depth of 99 ft. Uranium concentrations appear to be relatively stable in the zone from 52 to 62 ft, decreasing in the interval 62 to 65 ft, increasing between 73 and 81 ft, and increasing below 89 ft.

Historical tank farms gross gamma-ray log data from 1974 to 1993 were reviewed. The earliest log data show a zone of elevated gamma-ray activity at a depth of about 53 ft. The gamma intensity at 53 ft remained relatively stable from the earliest to most recent log data. This gamma-ray activity is related to the processed uranium contamination identified with the SGLS.

Randall and Price (2001) evaluated the GTP from 48 to 94 ft in gross gamma data collected between 1975 and 1993. This zone was subdivided into two subintervals: 48 to 68 ft and 68 to 94 ft. For the upper portion, the GTP increased from 1975 to 1978, and may have exhibited a small increase from 1987 to 1993. An evaluation of the stack plots over the 20 years for which data are available shows contaminant movement from the upper interval to the lower interval. The GTP in the lower interval has been continuously increasing since 1980. The overall interval from 48 to 94 ft is characterized as “unstable.”

Between July 2001 and March 2003, seven log runs were conducted with the RAS for the interval between 50 and 95 ft. A comparison between these runs and the 1995 SGLS data indicates the same general character and there is no significant difference between successive RAS logs. A comparison of log data from March 2003 with log data collected in November 2002 shows no evidence of any short-term increase in gamma activity that might be associated with the dissolution studies.

A neutron moisture log collected on November 12, 2002 shows no evidence of grout between the ground surface and 20 ft. From 0 to 52 ft, the volumetric moisture content ranges from 4 to 7 percent, with thin zones at 4.5 ft (13%), 29.5 (9%), and 36.5 ft (10%). A peak value of 15 percent occurs at 53 ft that coincides with the maximum uranium concentration. From 54 to 75 ft, the moisture content ranges from 2 to 4 percent, with peaks of 11 percent at 64.5 ft and 8 percent at 70 ft. From 75 to 86 ft, volumetric moisture content ranges from 4 to 7 percent. Between 86 and 112 ft, moisture content varies between 5 and 9 to 12 percent in what appears to be a thinly bedded sequence.

A second neutron moisture log was completed on March 6, 2003. A comparison of the two moisture logs indicated an increase of about 2 vol % water in the upper 8 ft, with no significant change in moisture content below 8 ft. The observed changes in moisture in the upper 8 ft can be attributed to infiltration of precipitation.

5.0 Summary of Results

Borehole logs in the vicinity of tank U-107 indicate the presence of low levels of shallow ^{137}Cs contamination, generally less than 10 pCi/g. This contamination is related to previous surface spills and/or pipeline leaks associated with tank farms operations. It generally occurs within the upper 30 ft, with the majority of the contamination in the upper 10 to 15 ft.

Man-made uranium (^{235}U and ^{238}U) was detected in the subsurface to the north and west of tank U-107. The maximum ^{238}U concentration occurs in a thin (less than 1 ft) zone at 53-ft depth. The highest measured ^{238}U concentration is 1,240 pCi/g in borehole 60-07-11. According to driller's logs for boreholes 60-07-10 and 60-07-11, contamination was encountered at this depth when the boreholes were drilled in 1976 and 1974, respectively. This contamination occurs approximately 12 to 14 ft below the base of the tank farm excavation. Figure 21 (from DOE 2000) shows the estimated extent of the uranium plume at a depth of 56 ft.

The source of the uranium contamination appears to be a leak in tank U-104. A discussion of this tank is provided in DOE (1996a). Tank U-104 had stored metal waste from T Plant operations since 1947. Beginning in 1953, tank U-104 was periodically sluiced to remove waste for uranium recovery. During sluicing operations in 1956 a bulge was discovered in the tank bottom. A subsequent investigation (Smith and Shadel 1956) showed a vertical bulge of about 5 ft near the center of the tank. A tear in the steel liner was discovered. At the time sluicing was discontinued, tank U-104 was estimated to contain about 10 tons of uranium (Clukey 1956). Water had been added to the tank during sluicing, and additional water was added during a leak test following discovery of the bulge. A leak volume of 55,000 gal was estimated in 1958 (Anderson 1990), but details of the leak estimate are not known. The visualizations shown in the tank farm report and the addendum to the tank farm report show a plume extending southward from the area between tanks U-104 and U-105.

Neutron moisture log data in these boreholes indicate an increase in volumetric moisture content that appears to coincide with the zone of maximum uranium contamination. The elevated moisture content is also observed in the other boreholes around tank U-107 in which uranium was not detected. A distinct increase in ^{40}K concentration also occurs at about the same depth. The elevated moisture and increase in ^{40}K correspond to a contact within the Hanford formation between silty sandy gravel and underlying silty sand. This contact appears to be controlling movement of the uranium plume from tank U-104.

A comparison between neutron moisture data collected in March 2003 (after the dissolution tests has been completed), with moisture data collected in November 2002 (prior to dissolution tests), shows no evidence of an increase in moisture associated with the dissolution studies. In boreholes without surface grouting (60-07-02, 60-07-11, 60-10-01, and 60-08-04) an increase in volumetric moisture content of about 1 to 2 percent is observed. This increase is most likely attributable to downward migration of precipitation.

Historical data and more recent log results indicate the uranium plume at 53 ft is relatively stable. However, there is evidence of downward migration in three of the four boreholes where uranium was detected. The deepest occurrence of uranium was detected in borehole 60-07-11. In the 1995 log, uranium was detected to a depth of about 93 ft. By 2001, the lower extent of the uranium plume had moved downward to 99 ft. Similar downward migration is observed in boreholes 60-07-10 and 60-07-01. Figure 22 shows ^{235}U and ^{238}U profiles from the 1995 and 2001 logs in boreholes 60-07-01, 60-07-10, and 60-07-11. SGLS results are discussed in more detail in the annual monitoring report for FY 2002 (DOE 2003).

6.0 Conclusions

Tank U-107 is characterized as sound, and no log data evaluated to date have provided information to dispute this categorization. Furthermore, a comparison of both RAS logs and neutron moisture logs between November 2002 and March 2003 indicated no changes in either gamma activity or soil moisture content that would be indicative of a leak or spill associated with the saltcake dissolution tests conducted between the two log events. However, only seven boreholes are located in the vicinity of a tank that has a circumference of almost 240 ft. The possibility of a leak from the tank sidewall or bottom cannot entirely be disproved solely from geophysical logging, unless many more boreholes can be installed. As more boreholes are installed, decreasing the distance between monitoring points, the probability of detecting a leak improves, but it is likely that a borehole monitoring system capable of detecting all leaks of significant volume would be prohibitively expensive. Leaks from the tank bottom near the center would even then likely go undetected.

On the south side of tank U-107, boreholes 60-10-01, 60-10-11, and 60-08-04 are located relatively far from the tank wall. No boreholes are located in the vicinity of the spare inlet nozzles in the southeast quadrant of the tank. The spare inlet nozzles are known to be a source of leaks on other single-shell tanks, particularly where overfilling occurred. Approximately 14,900 gal of water were added to U-107 during the dissolution test, and no indication of any significant loss is evident. The observed increase in soil moisture in the upper 10 ft of the vadose zone appears to be related to infiltration of precipitation from an unusually wet winter. A review of precipitation data from the Hanford Meteorological Station (http://etd.pnl.gov:2080/HMS/) indicated that cumulative precipitation for November through February was 5.43 in., which is 1.79 in. above normal value for this period. The majority of the additional precipitation fell in December and January as rain.

The preexisting uranium plume on the north and west side of tank U-107 is associated with the documented leak in tank U-104. Lateral migration appears to have occurred prior to 1974 along a fine-grained horizon at a depth of approximately 53 ft. Downward migration from a thin zone at 53 to 55 ft appears to be continuing since at least 1995. This contamination plume is unrelated to tank U-107. A thin fine-grained bed or stratigraphic contact is evident at 52- to 53-ft depth in all boreholes around tank U-107. On the north, this thin bed is associated with the uranium plume from U-104. Other zones of interest were identified from the moisture data at 63 to 65 ft and 83 to 110 ft.

Although there is no evidence of a short-term impact from the dissolution tests, the possibility of a leak cannot entirely be refuted solely from the borehole log data. Moreover, the long-term behavior of the observed moisture increase in the shallow vadose zone is important in predicting future contaminant migration. Moisture logs should be collected again at a later date to determine the fate of the shallow infiltration. Finally, the uranium plume associated with tank U-104 should be monitored to determine if the movement observed between 1995 and 2001 is continuing. For these reasons, boreholes in the vicinity of tank U-107 should be re-logged in approximately 3 months. Available data suggest that the ongoing movement of the uranium plume on the north side of tank U-107 is not rapid enough to be evident in routine quarterly monitoring. If the next scheduled monitoring events show no evidence of changes, the monitoring interval for the boreholes on the north side of tank U-107 should be increased to yearly. Boreholes 60-07-02, 60-10-01, and 60-10-11 can be monitored less frequently; the monitoring schedule for these boreholes should return to the minimum recommended frequency of once in 5 years.

Figures

The following section presents the figures cited in this report in the order in which they were presented.

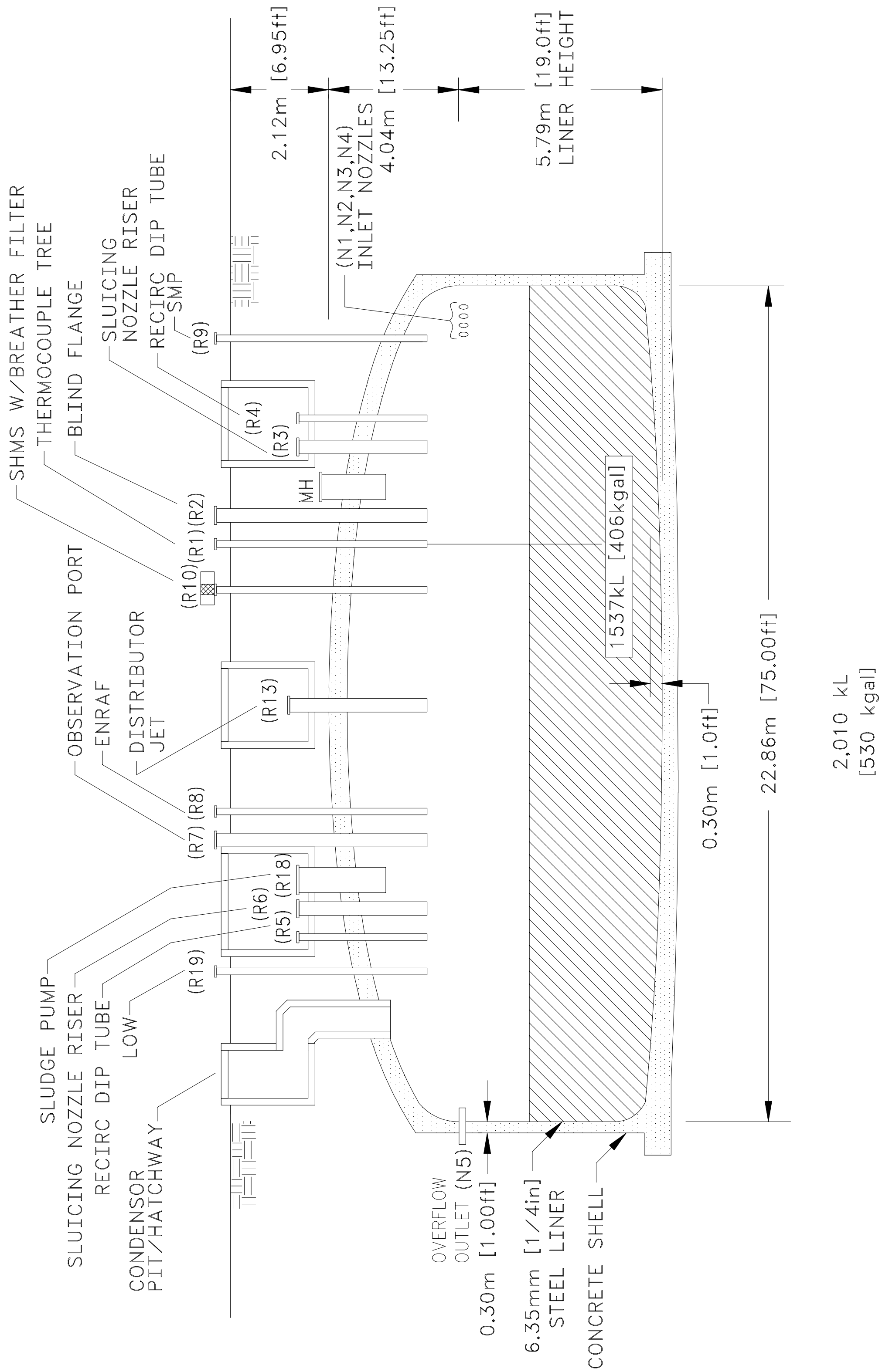


Figure 1. Section View of Tank U-107

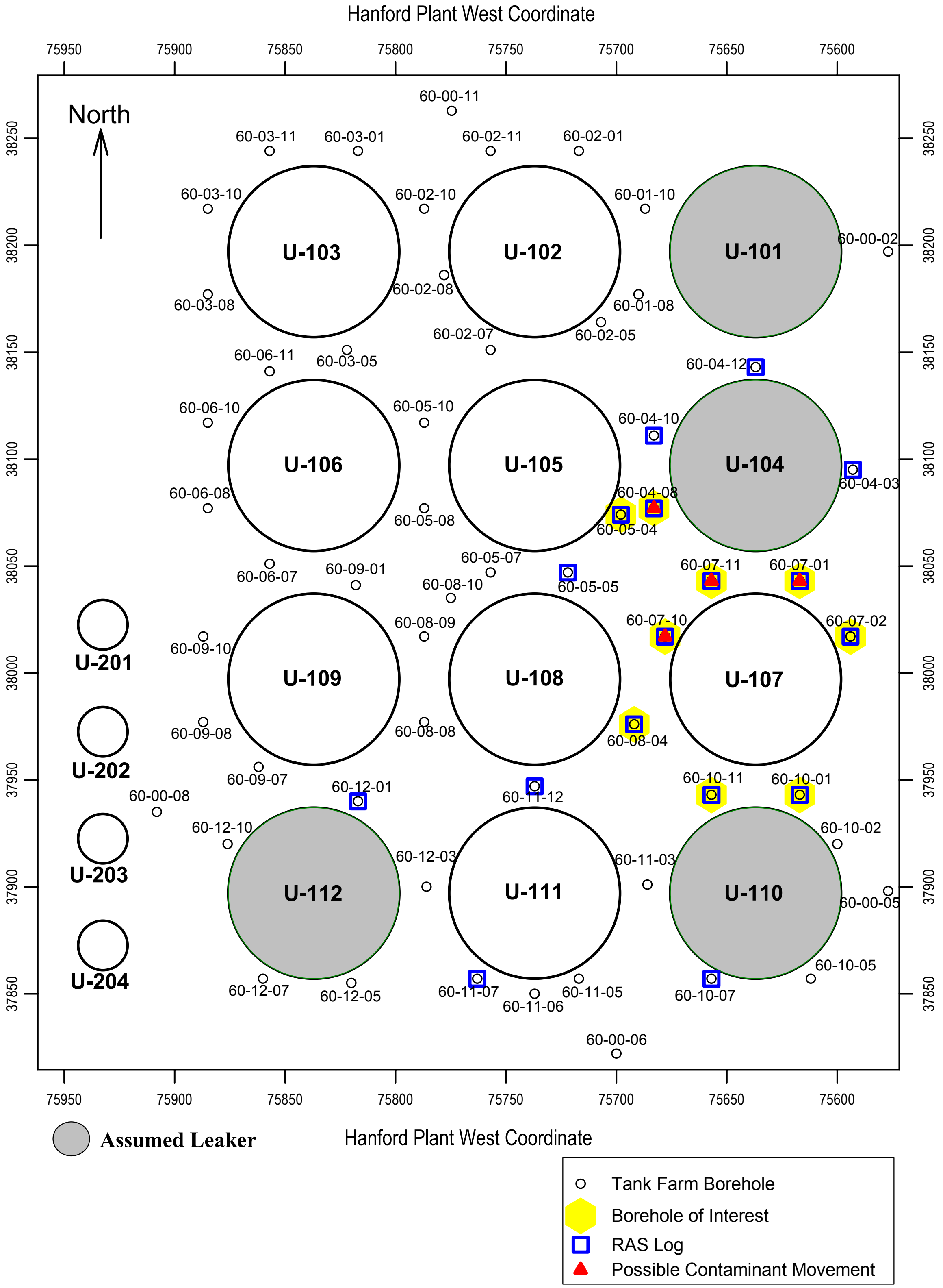


Figure 2. Location of Monitoring Boreholes in the Vicinity of Tank U-107

60-07-01 Combination Plot

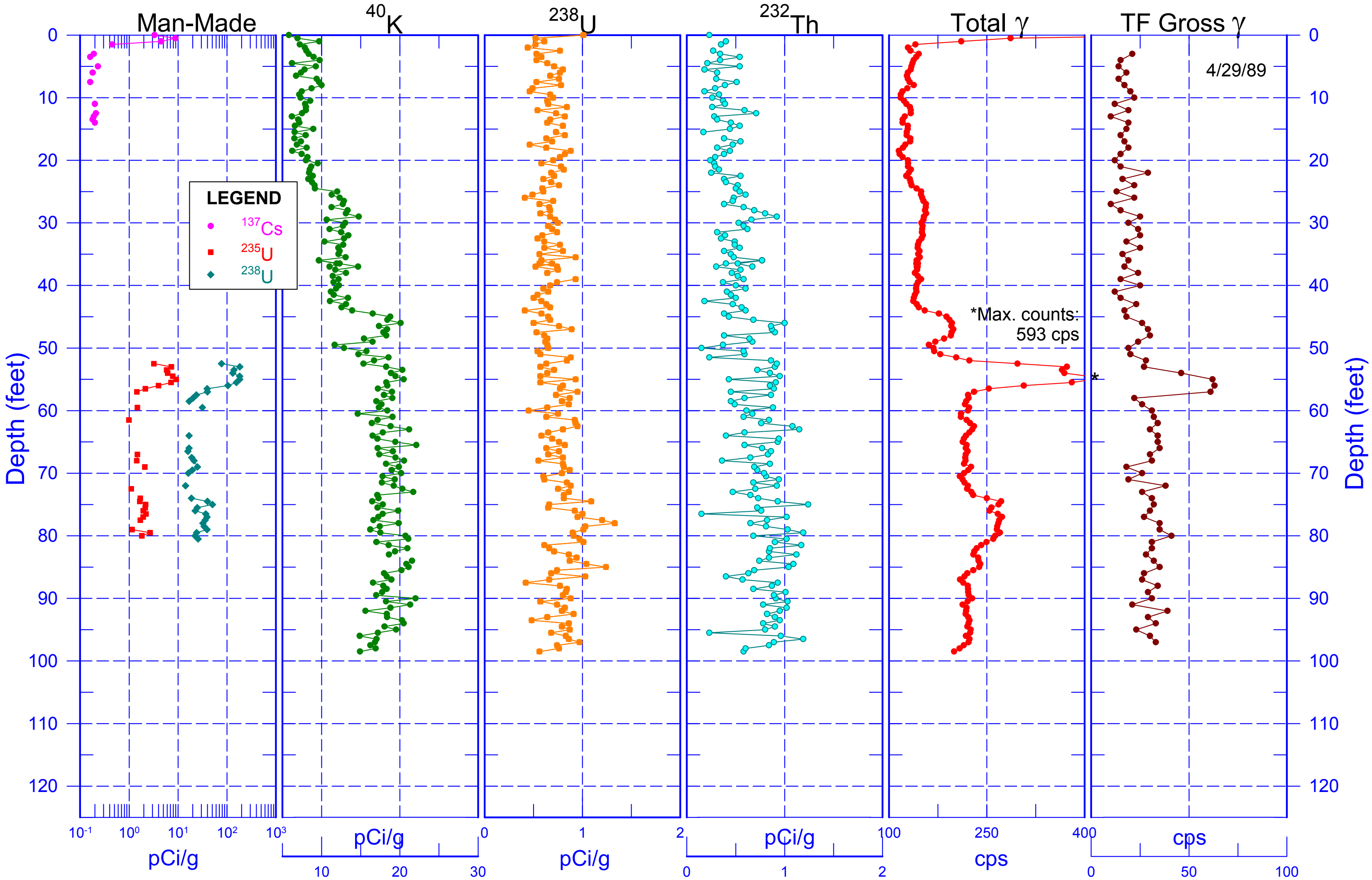


Figure 3. Combination Plot for Borehole 60-07-01

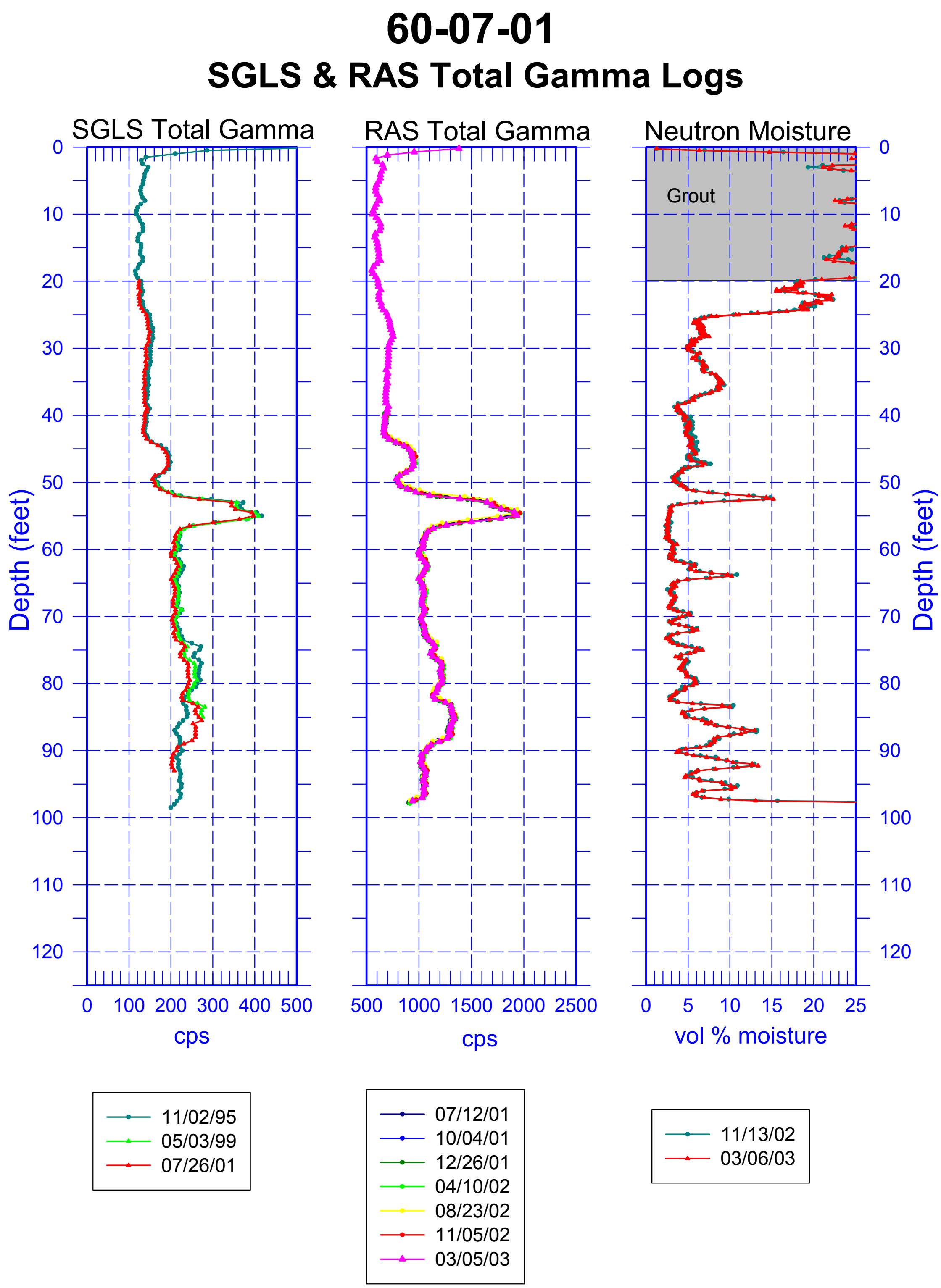


Figure 4. SGLS and RAS Total Gamma Logs for Borehole 60-07-01

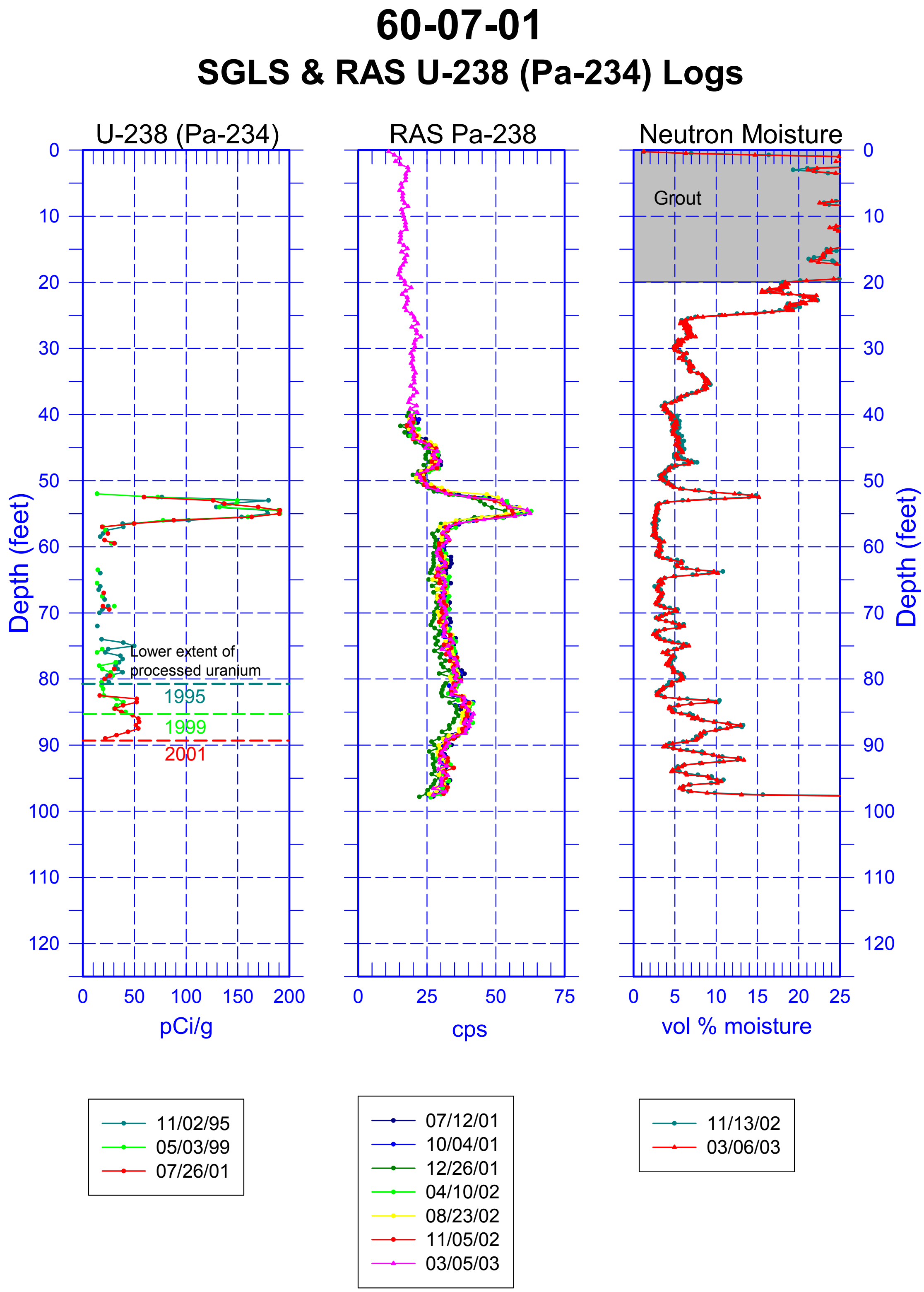


Figure 5. SGLS and RAS U-238 Logs for Borehole 60-07-01

60-07-02 Combination Plot

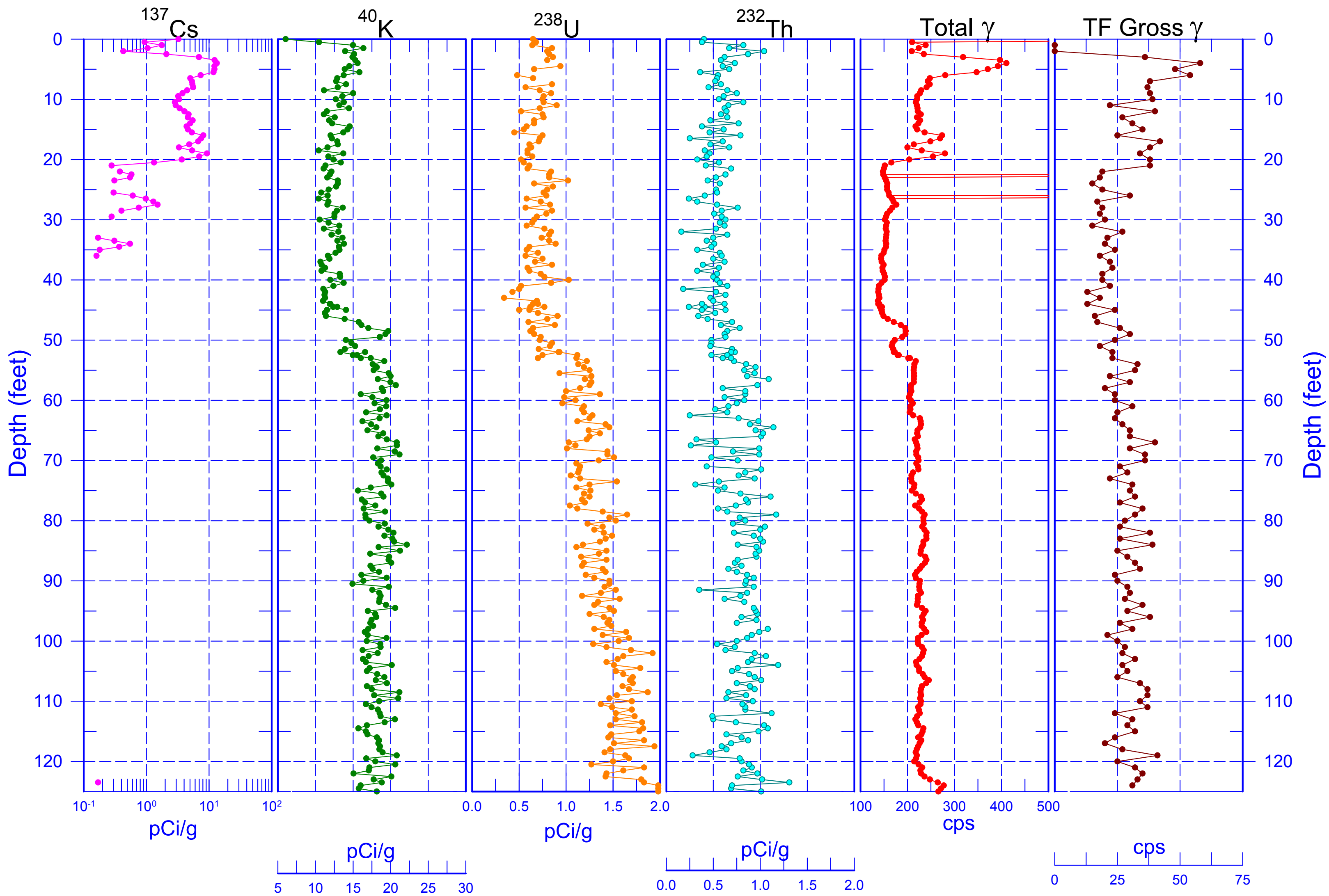


Figure 6. Combination Plot for Borehole 60-07-02

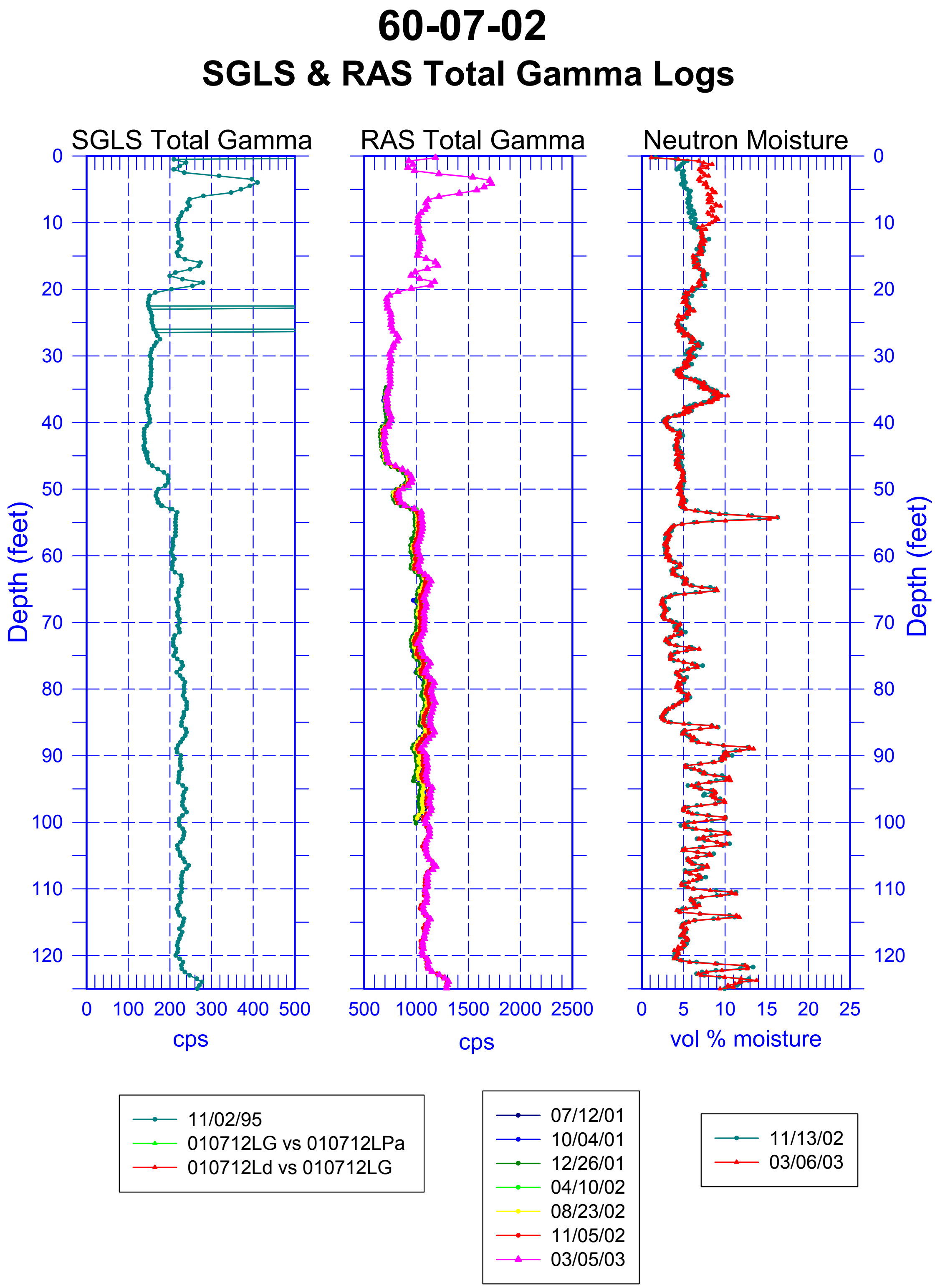


Figure 7. SGLS and RAS Total Gamma Logs for Borehole 60-07-02

60-10-01 Combination Plot

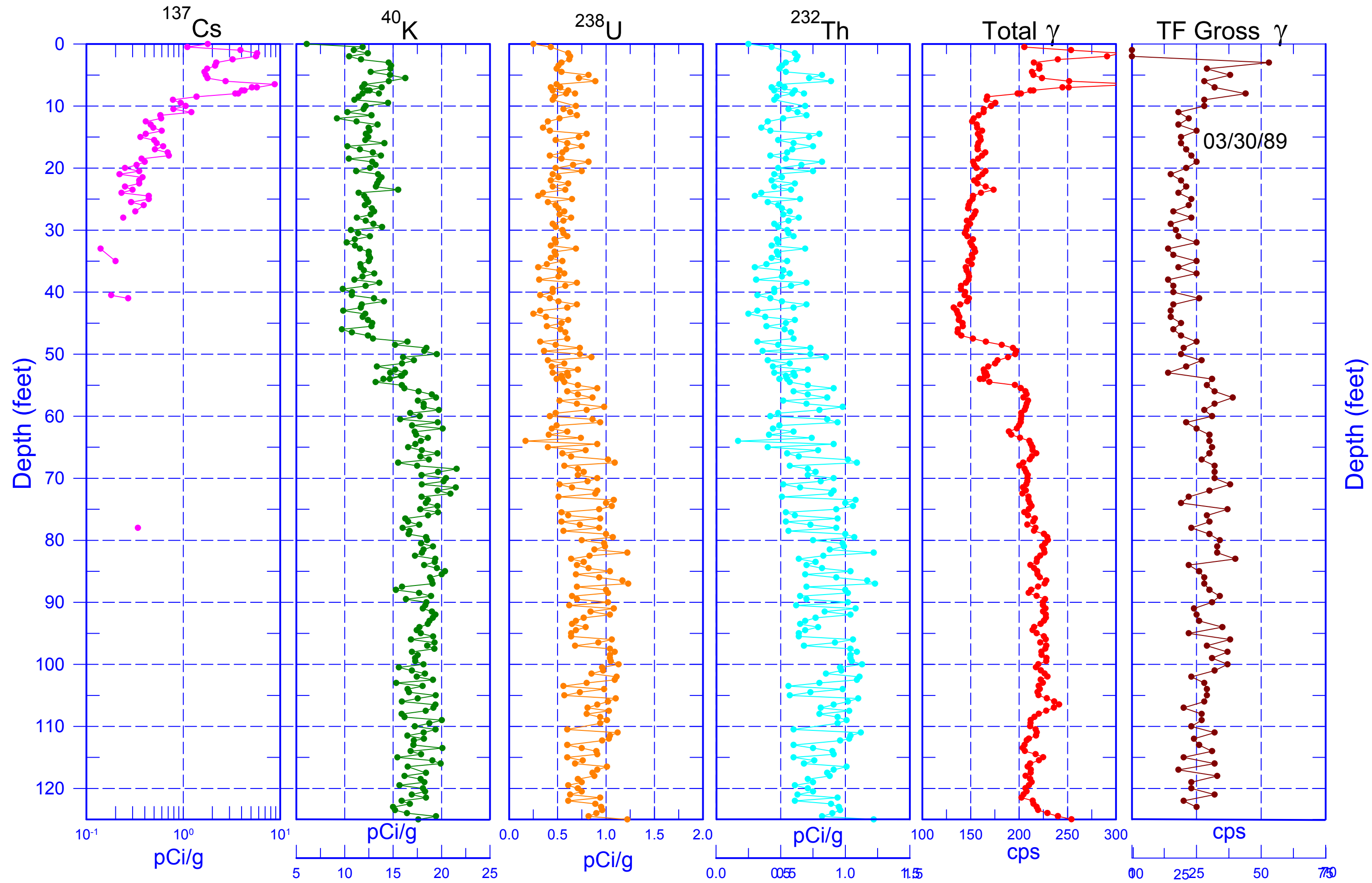


Figure 8. Combination Plot for Borehole 60-10-01

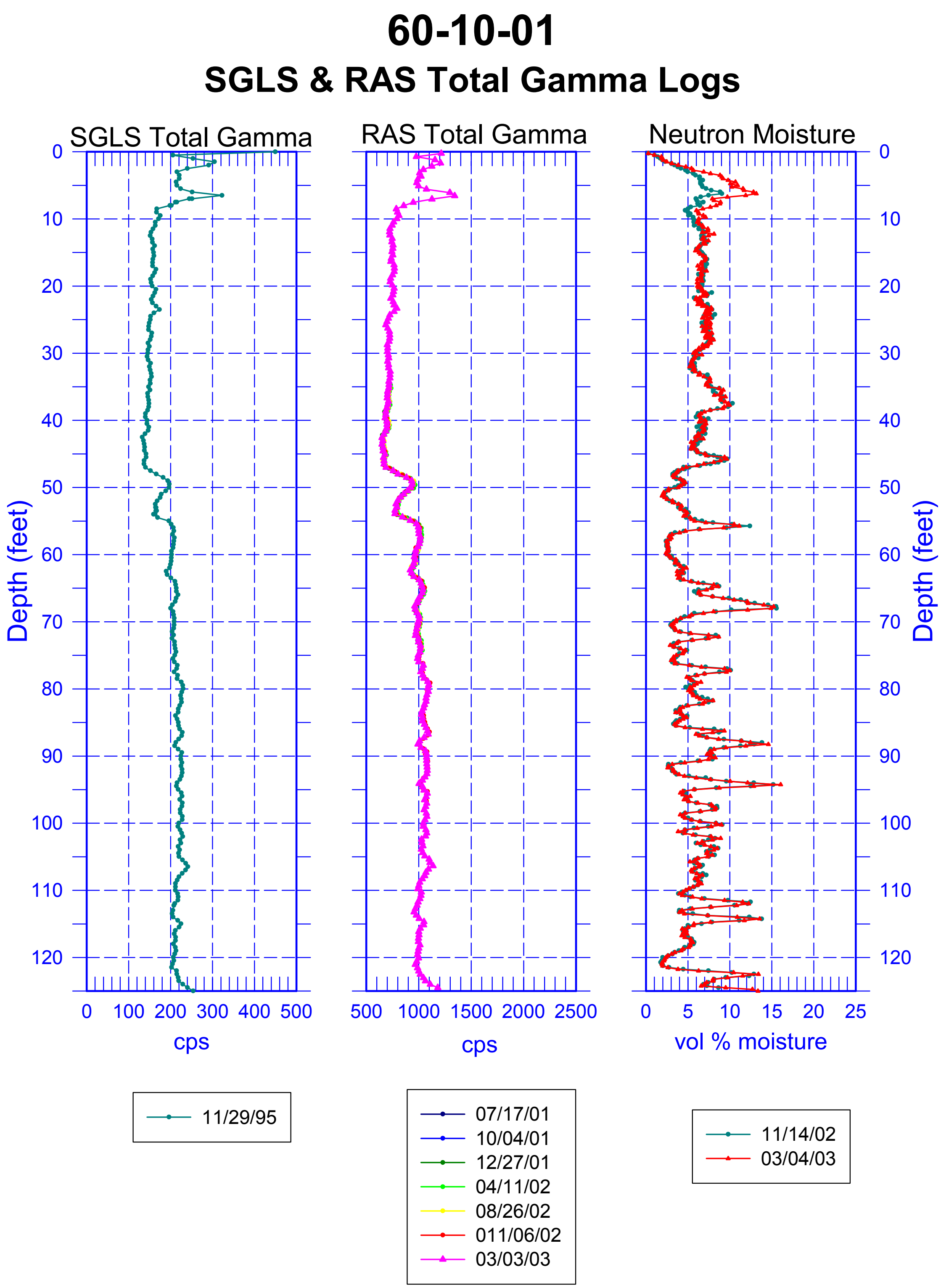


Figure 9. SGLS and RAS Total Gamma Logs for Borehole 60-10-01

60-10-11 Combination Plot

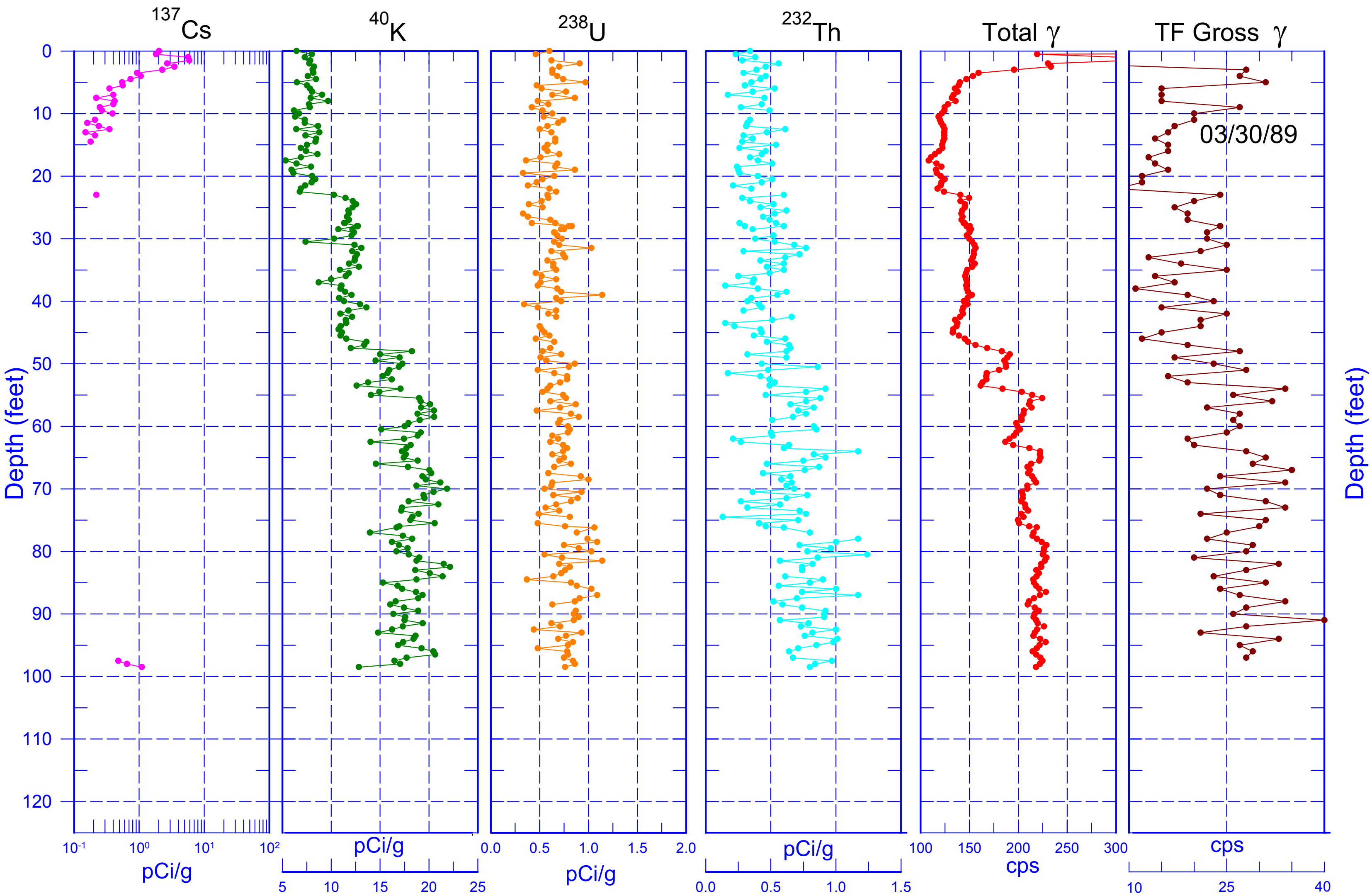


Figure 10. Combination Plot for Borehole 60-10-11

60-10-11
SGLS & RAS Total Gamma Logs

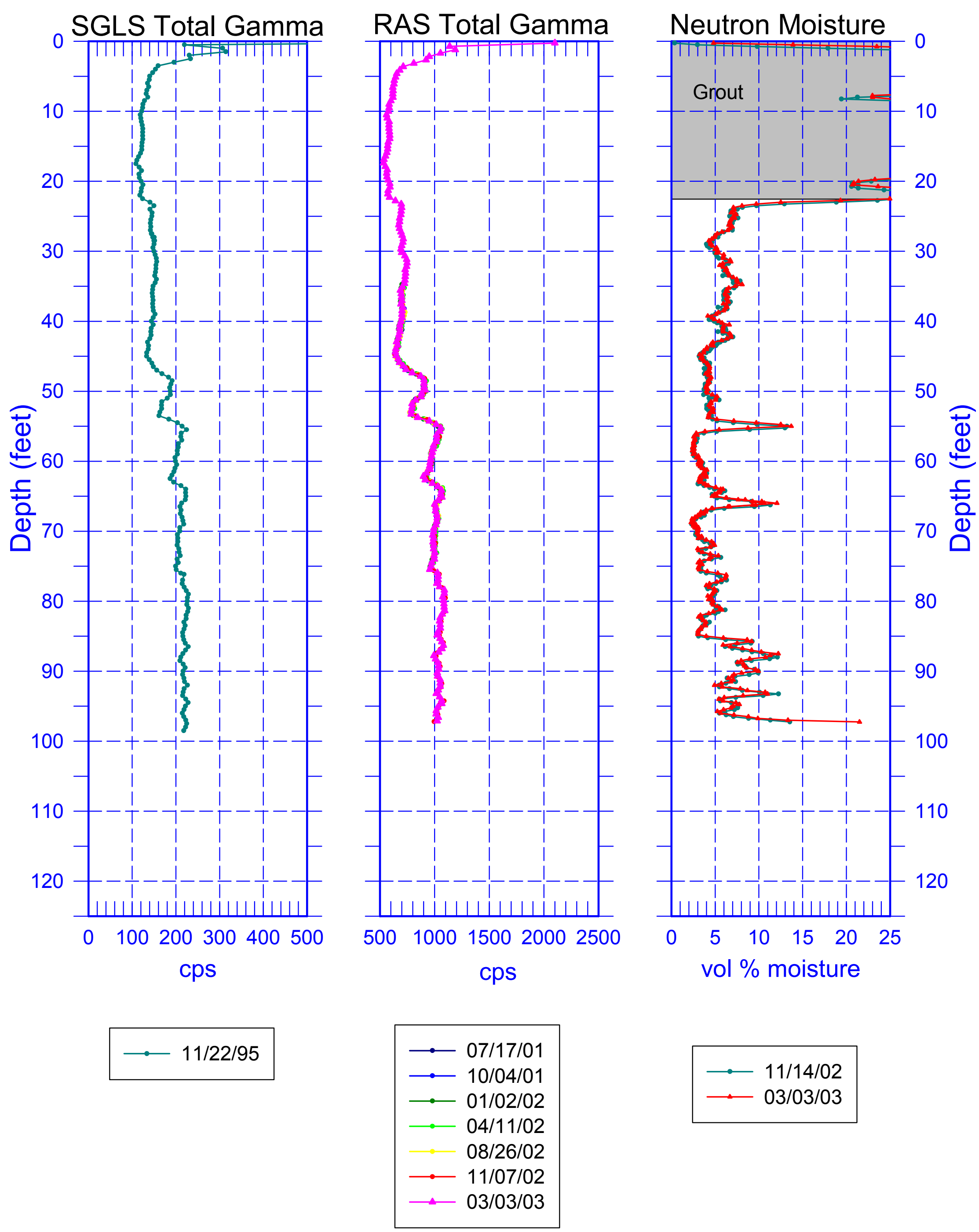


Figure 11. SGLS and RAS Total Gamma Logs for Borehole 60-10-11

60-08-04 Combination Plot

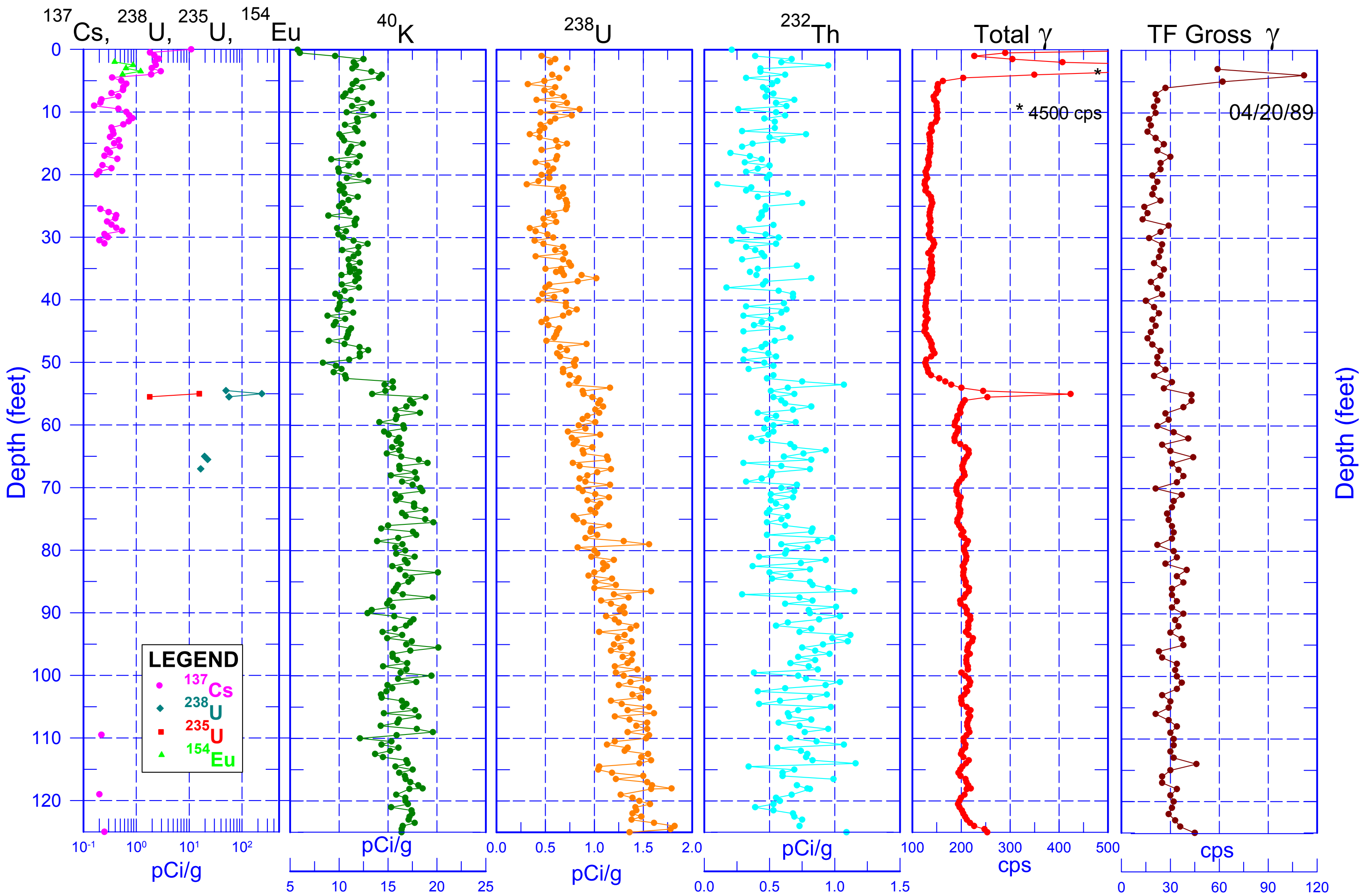


Figure 12. Combination Plot for Borehole 60-08-04

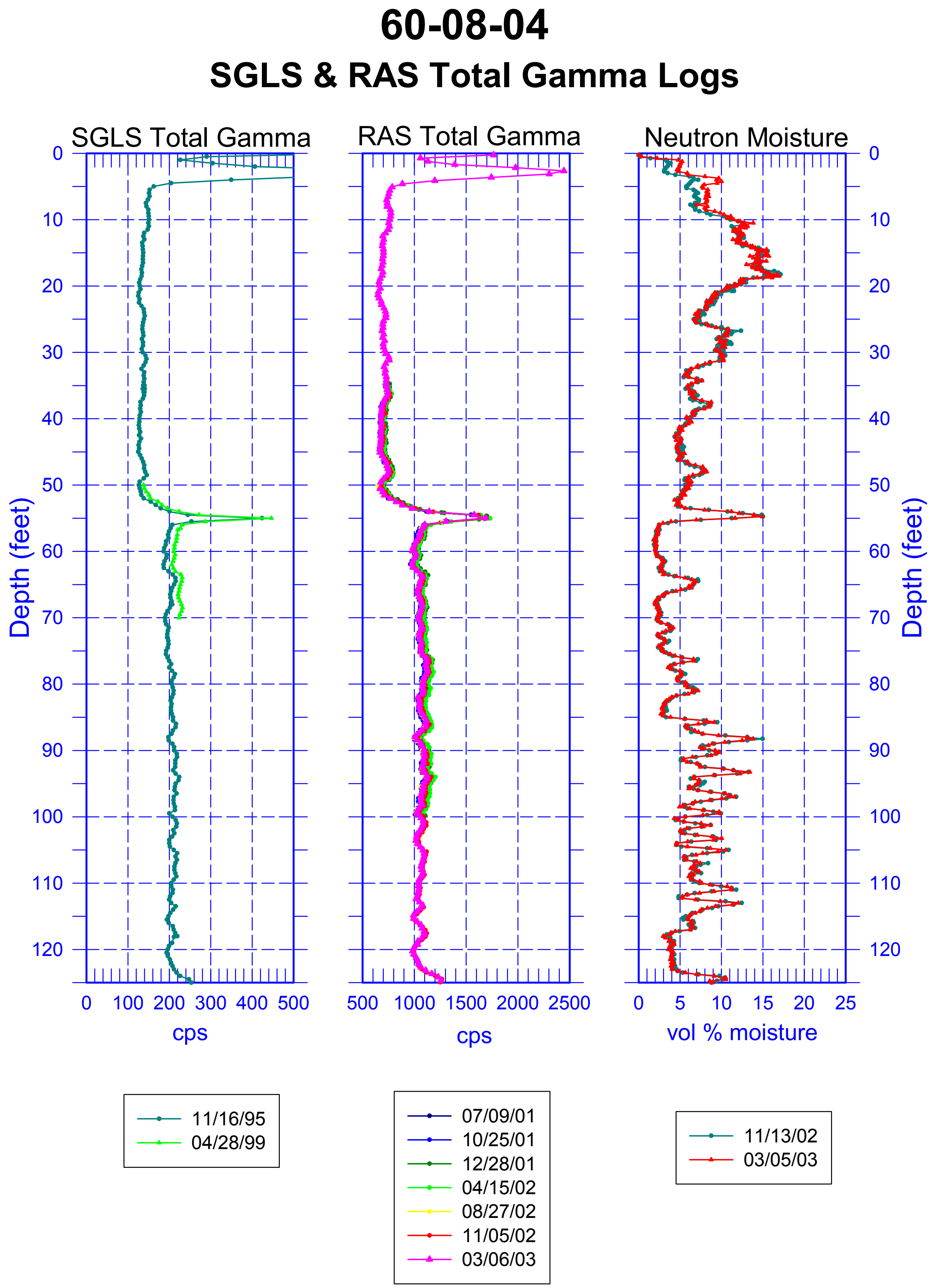


Figure 13. SGLS and RAS Total Gamma Logs for Borehole 60-08-04

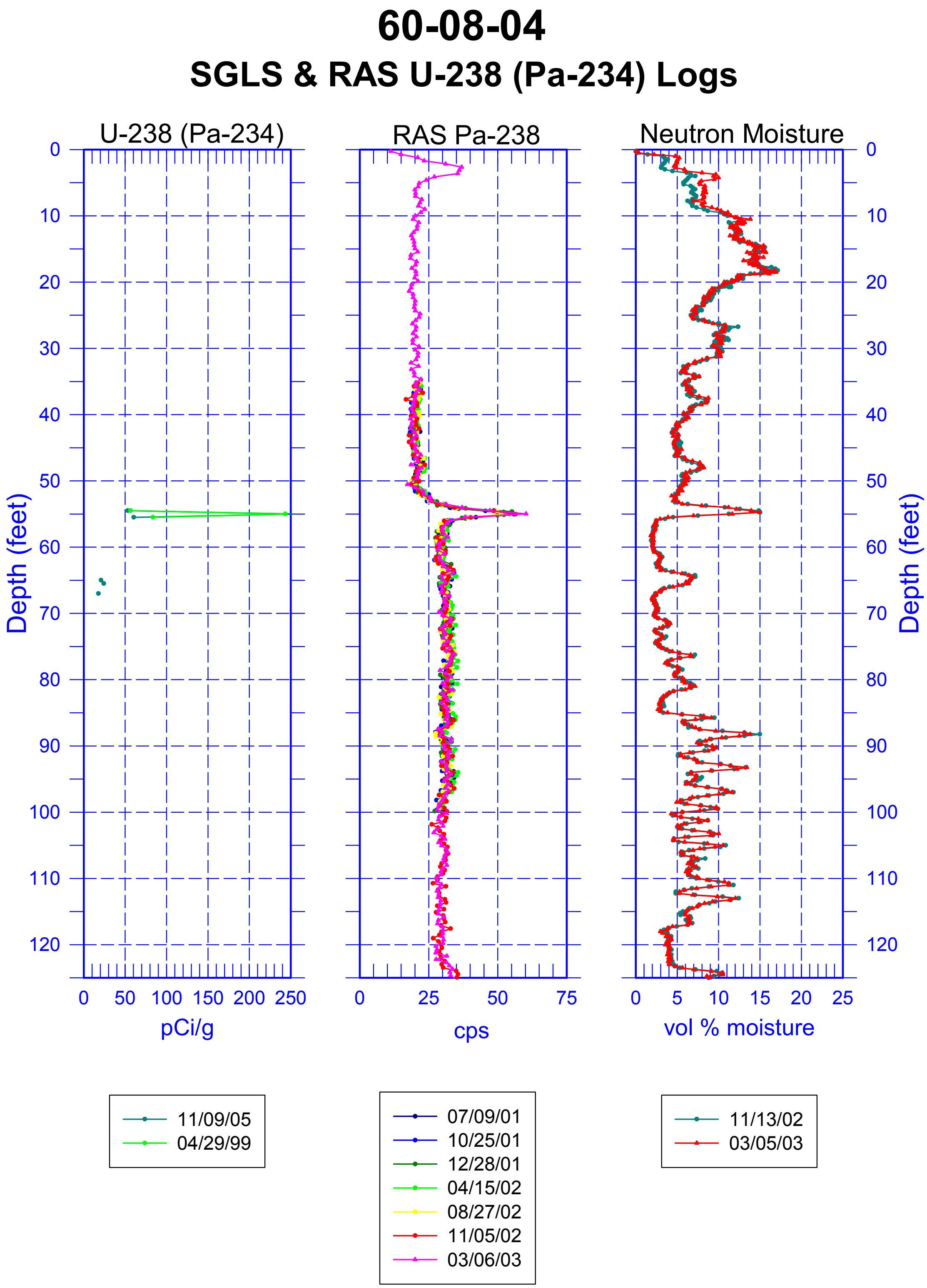


Figure 14. SGLS and RAS U-238 Logs for Borehole 60-08-04

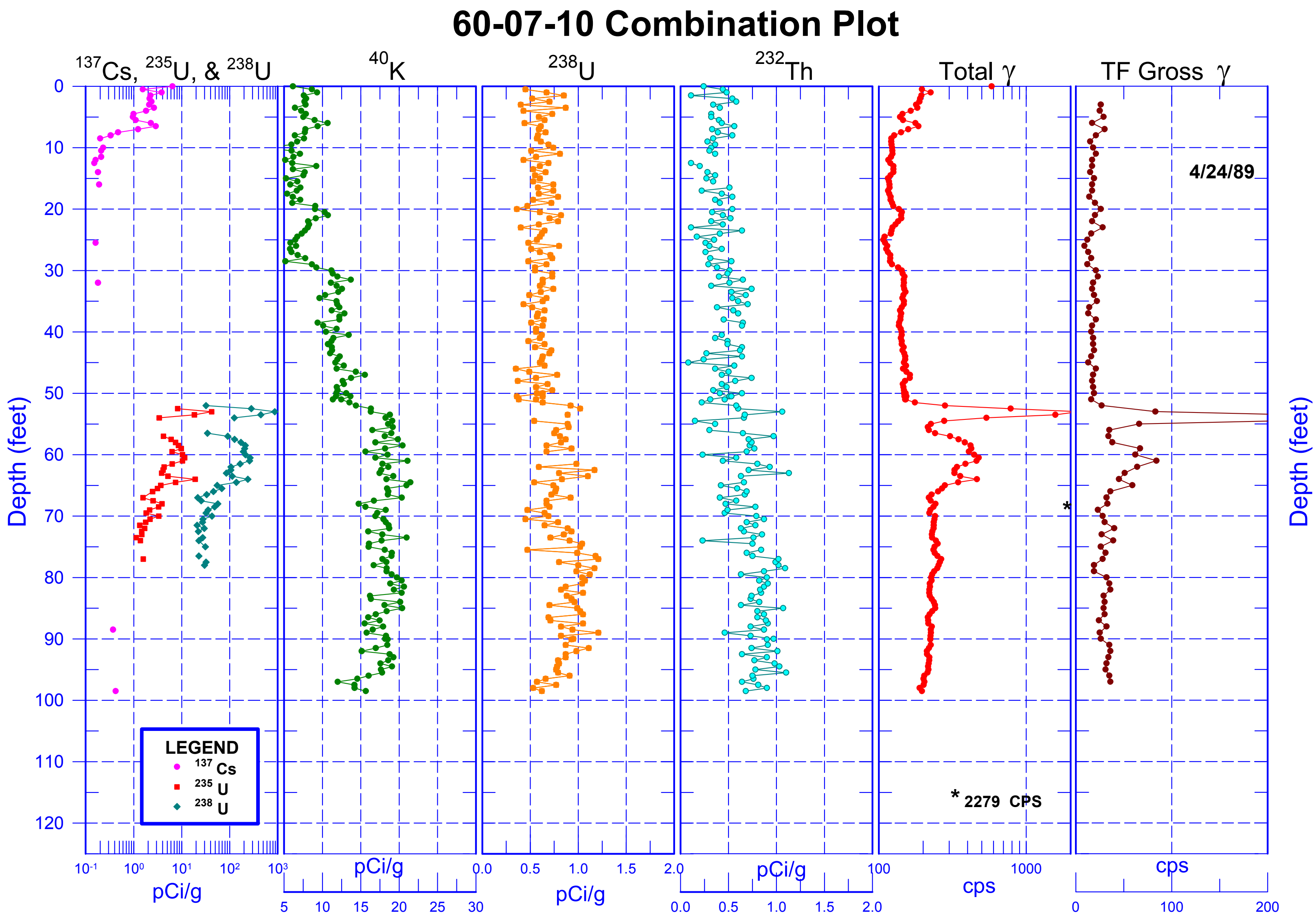


Figure 15. Combination Plot for Borehole 60-07-10

60-07-10
SGLS & RAS Total Gamma Logs

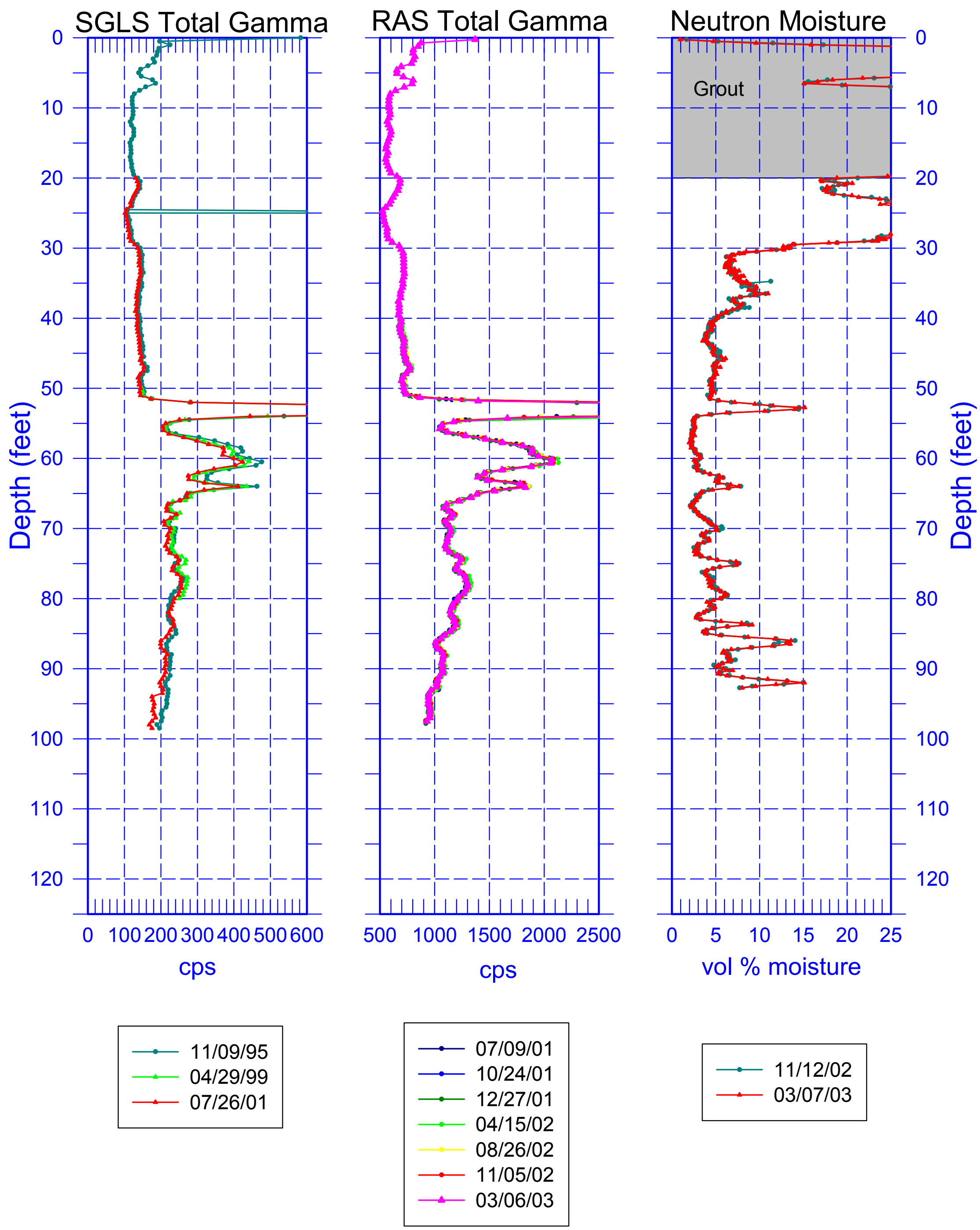


Figure 16. SGLS and RAS Total Gamma Logs for Borehole 60-07-10

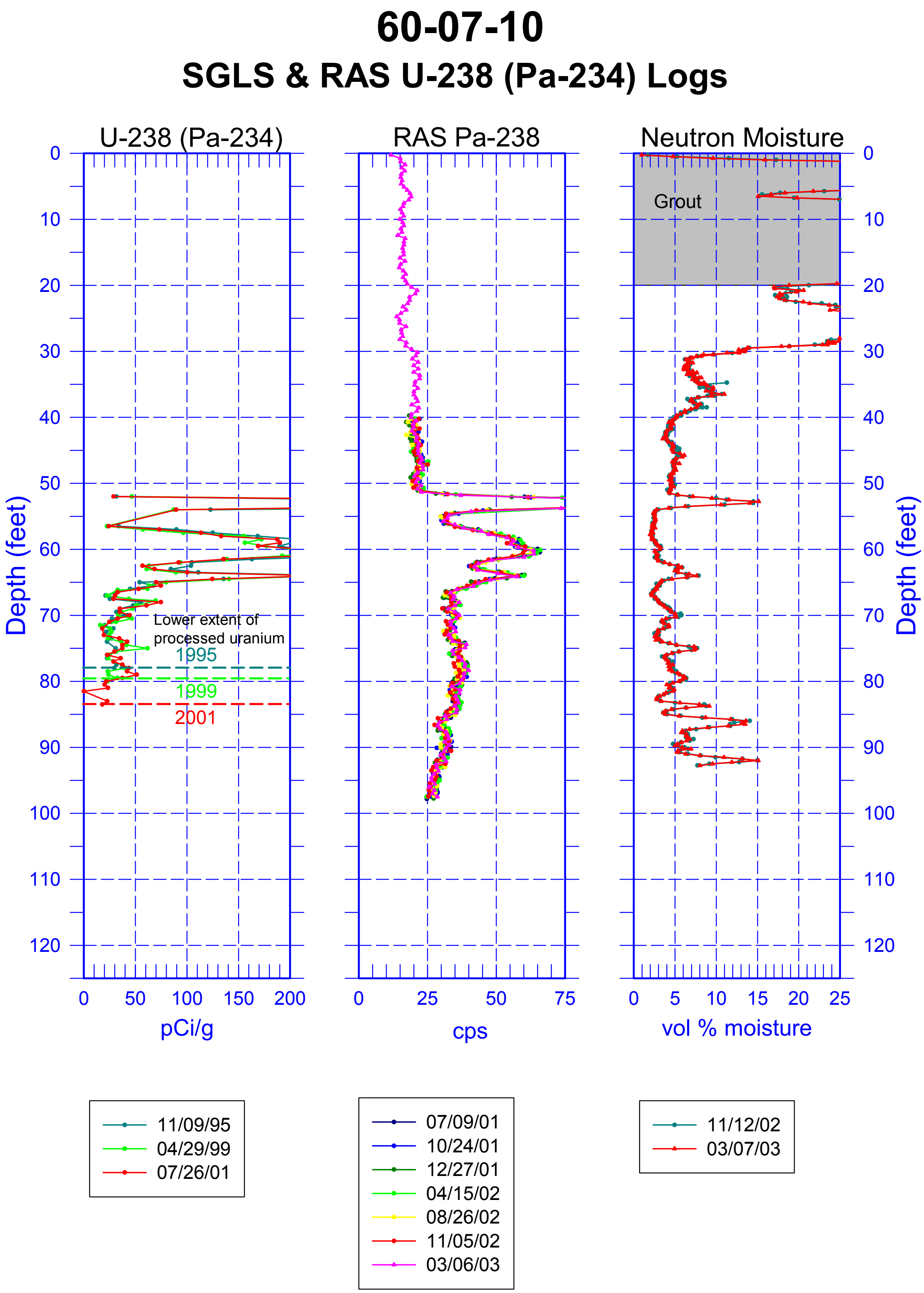


Figure 17. SGLS and RAS U-238 Logs for Borehole 60-07-10

60-07-11 Combination Plot

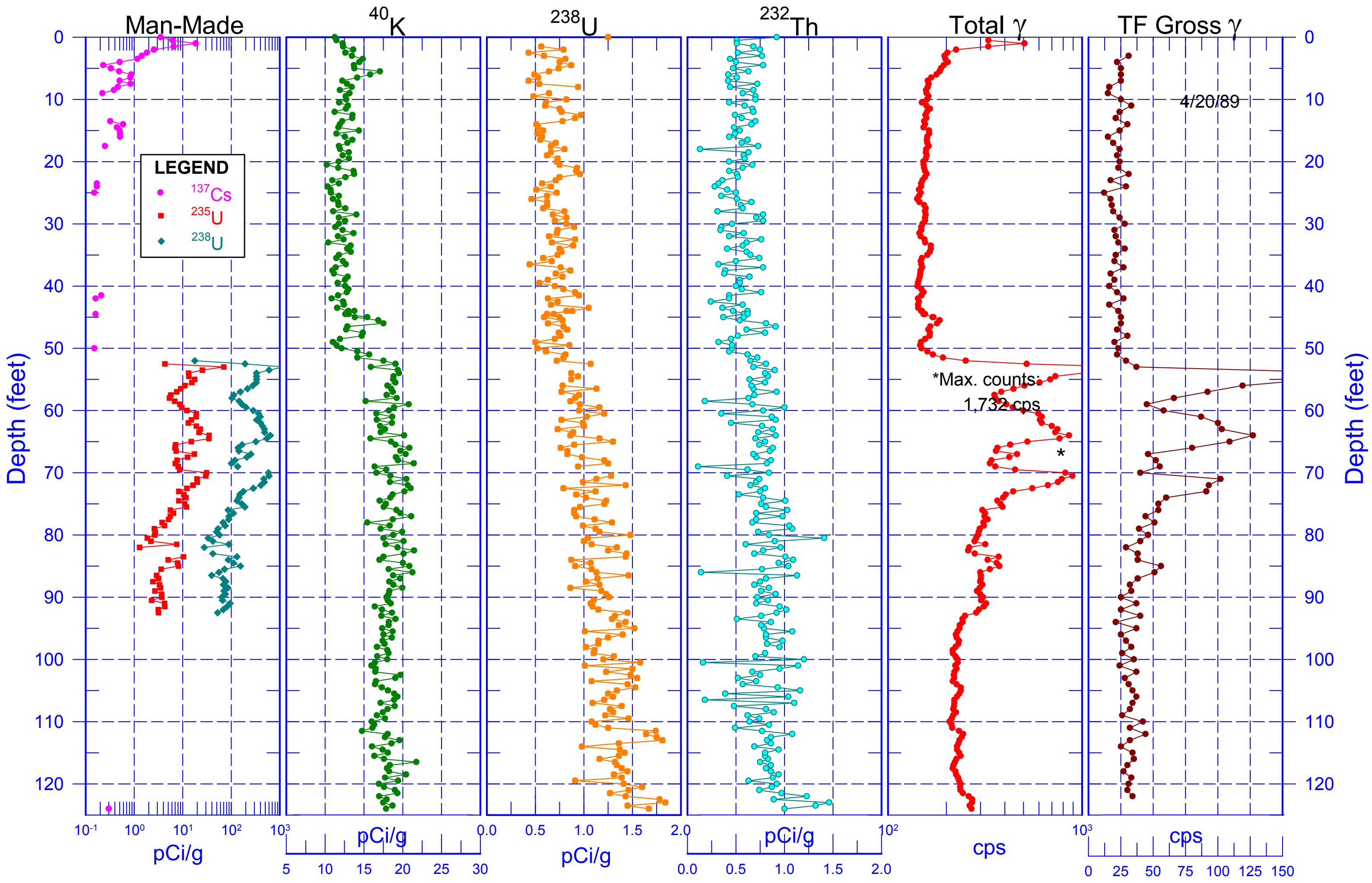


Figure 18. Combination Plot for Borehole 60-07-11

60-07-11
SGLS & RAS Total Gamma Logs

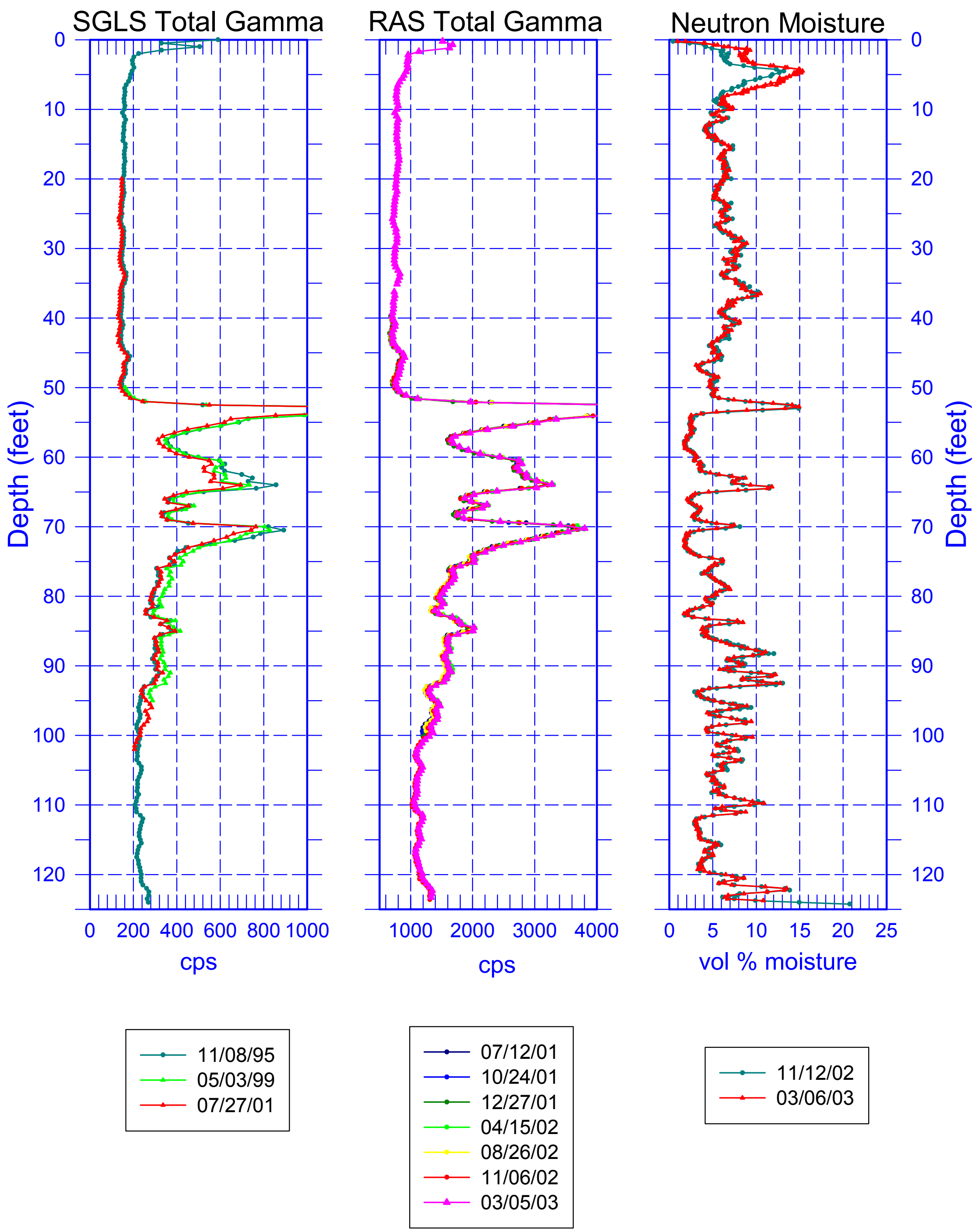


Figure 19. SGLS and RAS Total Gamma Logs for Borehole 60-07-11

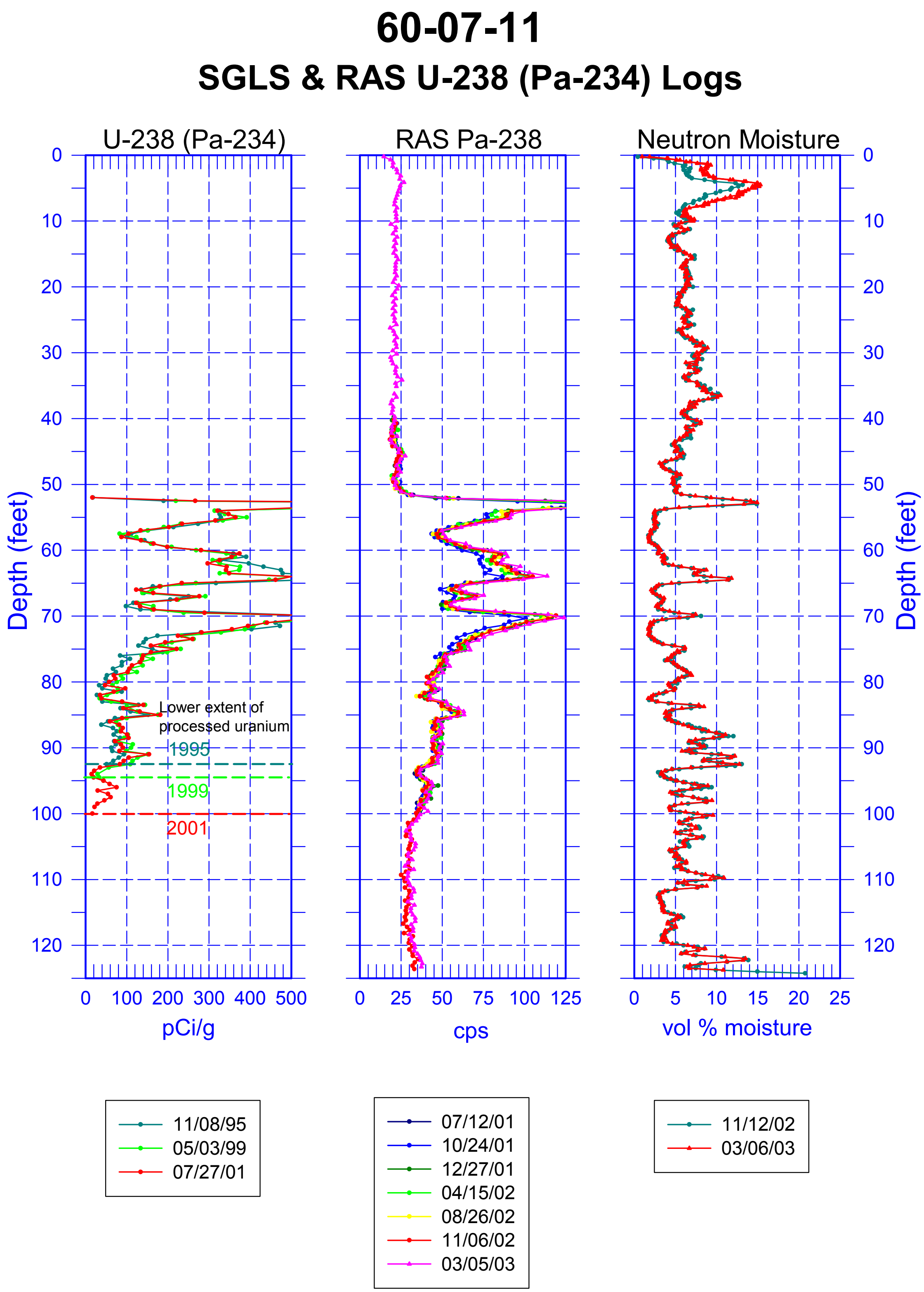
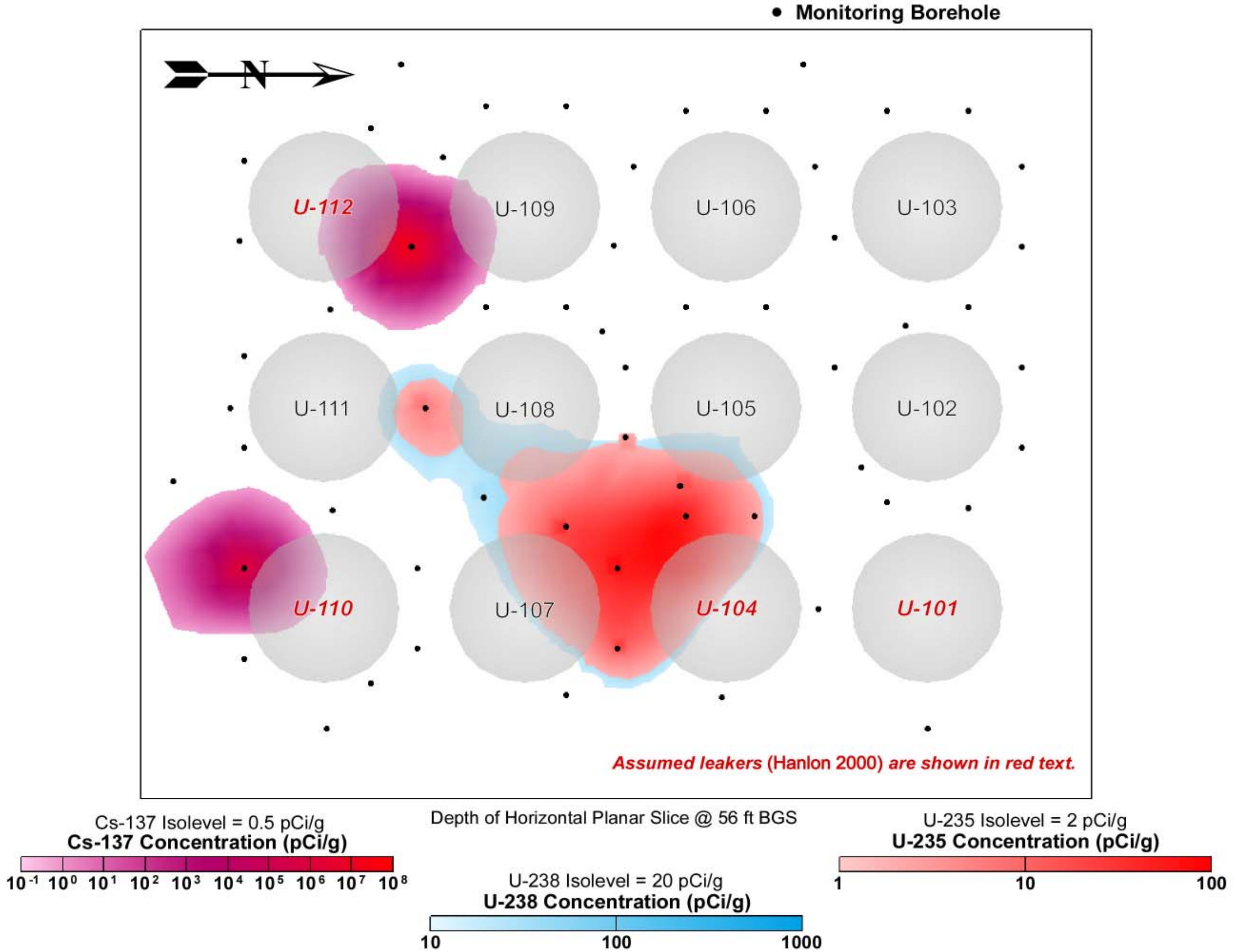


Figure 20. SGLS and RAS U-238 Logs for Borehole 60-07-11



from DOE (2000)

Figure 21. U Tank Farm Visualization

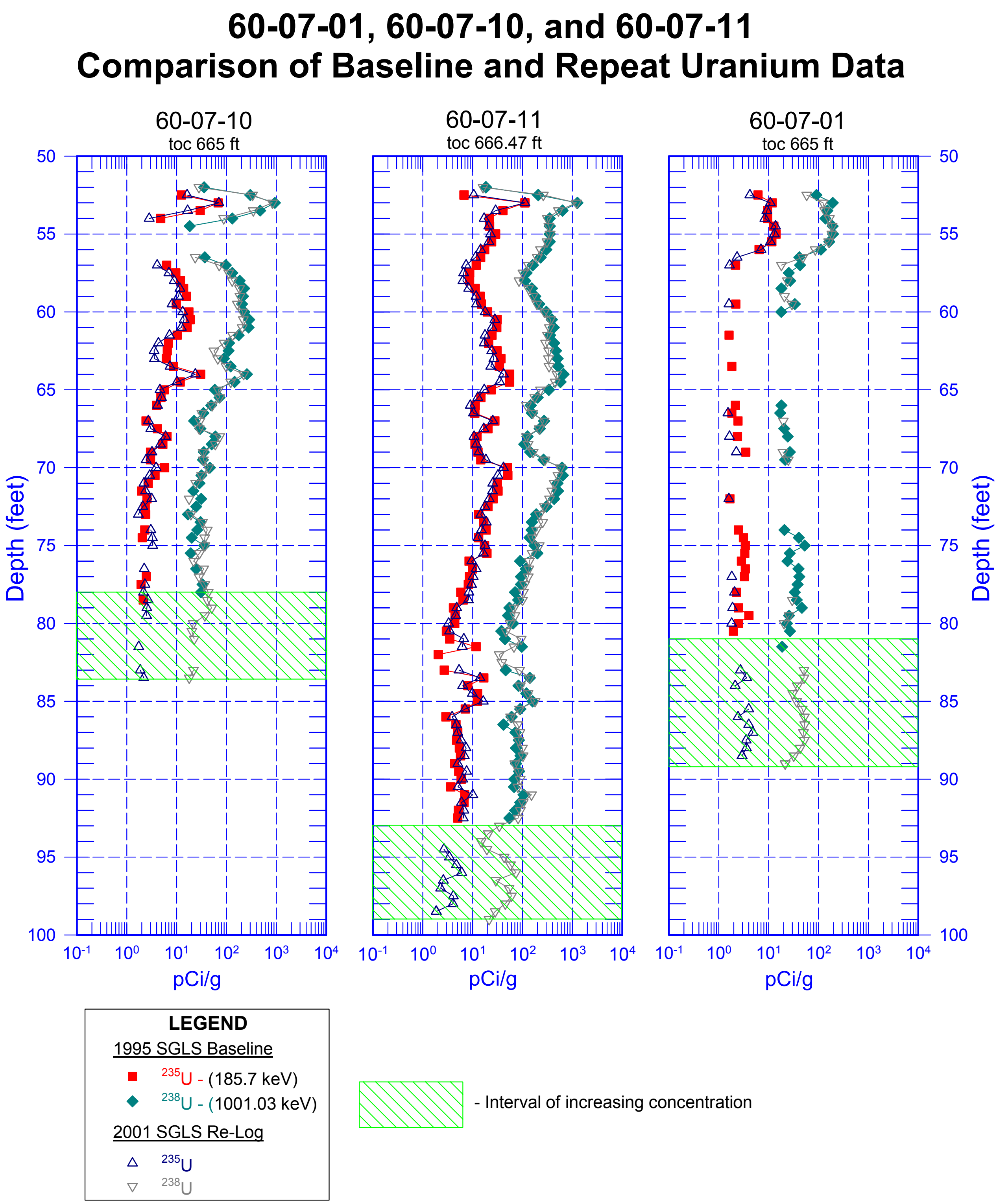


Figure 22. Comparison of Baseline and Repeat Data for Boreholes 60-07-01, 60-07-10, and 60-07-11

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